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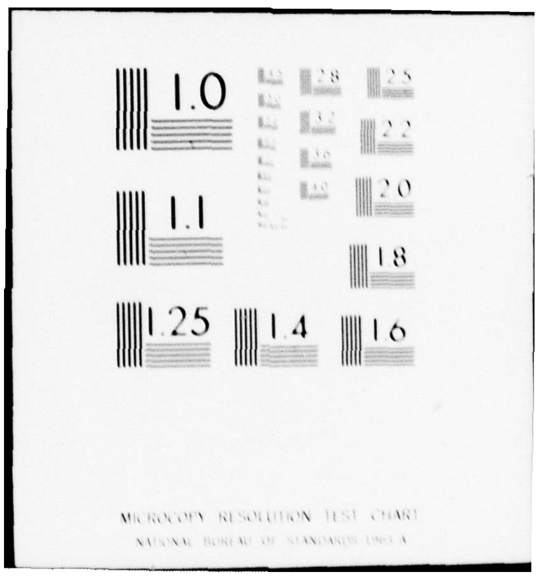
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AUTOMATIC INSPECTION, DIAGNOSTIC AND PROGNOSTIC SYSTEM (AIDAPS), TEST CELL DATA COLLECTION AND TECHNICAL SUPPORT

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J. V. HICKEY

AUGUST 1977

FINAL REPORT

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PREPARED FOR

DIRECTORATE FOR DEVELOPMENT AND ENGINEERING
U. S. ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
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Oil Monitoring	High Frequency
Vibration Monitoring	Condition Monitoring
Chip Detector	Helicopter
Drive Components	

This report includes:

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This final report covers the work accomplished by Bell Helicopter Company in direct support to the Automatic Inspection, Diagnostic and Prognostic System (AIDAPS) prototype development. Work covered in this next report are; test cell data for the AIDAPS developer to use in determining diagnostic and prognostic logic; collect engineering data and technical support for AIDAPS integration into the UH-1 and AH-1 aircraft; and providing technical representation at AIDAPS development sites. → (over)

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AIDAPS was intended for use in Army aircraft and was intended to be used to reduce maintenance cost and improve flight safety by continuous in-flight monitoring of aircraft subsystems.

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DAAJ01-71-A-0335(P2B)
Delivery Order 0007

BY J. V. Hickey — J. V. Hickey — DATE 3 Nov 1976

CHECKED R. B. Patten — R. B. Patten — DATE 15 DEC 1976

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LIST OF TABLES

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1.0 INTRODUCTION

This report describes the work accomplished by Bell Helicopter Textron (BHT) under USAAVSCOM Contract Number DAAJ01-71-A-0335 (P2B), Delivery Order Number 0007. This is the final technical report, submitted in accordance with Contract Data Requirement Sequence Number 004 of the R&D Basic Ordering Agreement.

2.0 OBJECTIVES

The Automatic Inspection, Diagnostic and Prognostic System (AIDAPS) is being developed by the U.S. Army Aviation Systems Command (USAAVSCOM) for use in Army aircraft. AIDAPS is intended to reduce maintenance costs and improve flight safety by continuous automatic in-flight monitoring of aircraft subsystems.

Previous programs (References 1 and 2) were completed at CCAD, Corpus Christi, Texas, and at the U.S. Army Headquarters and Installation Support Activity, Granite City, Illinois. A follow-on program to develop an AIDAPS prototype was awarded to the Airesearch Manufacturing Company, Torrance, California. The objective of the effort reported herein was to directly support the AIDAPS prototype development.

3.0 SCOPE

BHT furnished personnel, engineering services, facilities and equipment to provide data and support for the AIDAPS developer in three areas:

- Test cell data for the AIDAPS developer to use in determining diagnostic and prognostic logic.
- Engineering data and technical support for AIDAPS integration into UH-1 and AH-1 aircraft.
- Technical representation at AIDAPS development sites.

Engine related testing and technical support activities were subcontracted to AVCO Lycoming, and are separately reported per AVCO Lycoming Report No. LYC 76-56, November 1976.

As a part of the technical support task area, airframe and engine training schools were provided for the members of the AIDAPS development team by BHT and AVCO Lycoming.

4.0 RESULTS AND DISCUSSION

Twelve tasks were outlined in the BHT contract and delivery order to cover the objective and scope of work outlined above.

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The following paragraphs summarize the efforts and work accomplished.

4.1 Detailed Test Plan - Task I

The Task I plan outlining the test cell data collection and analysis of discrepant parts implanted in UH-1H and AH-1G engines, transmissions, and gearboxes was completed and submitted per References (3) and (4). The test plan outlined the test cell program to:

- Obtain baseline and malfunction signature data for the development of analysis techniques for implementation into prototype AIDAPS equipment.
- Validate parts as implant candidates.
- Obtain degradation rate data for use in failure prognosis.
- Provide statistical confidence that part removal thresholds occur by an adequate margin prior to failure.

4.2 Installation of Equipment - Task II

4.2.1 BHT Test Cell

The equipment installed for the BHT test cell data collection effort is detailed in Reference (4). The BHT test cell is illustrated in Figure 1. Make-up power into the slave transmission is provided by a 500 horsepower electric motor through an electro-magnetic coupling and speed-increasing gearbox. Make-up power is added to regenerative loop power in the slave transmission which drives the test transmission. Most of the power is circulated in the regenerative loop, that is,out of the mast of the test transmission through the overhead gearbox to the slave mast and into the slave transmission. Power in the regenerative loop is controlled by introducing torque into the loop by angular displacement of the lower ring gear with respect to the main case of the slave transmission. Torque in the loop is indicated by a strain gaged shaft in the overhead gearbox.

Power to the tail rotor drive train is taken from the tail rotor quill of the test transmission, transmitted through the 42-degree and 90-degree gearboxes, and dissipated by a water brake dynamometer at the output of the 90-degree gearbox.

4.2.2 Test Cell Instrumentation

The test cell instrumentation is illustrated in Figure 2. Accelerometer, RPM, voice and time data were recorded at the end of each stabilized diagnostic run condition and every 10th prognostic cycle as discussed in Section 4.3. During the Removal Limit

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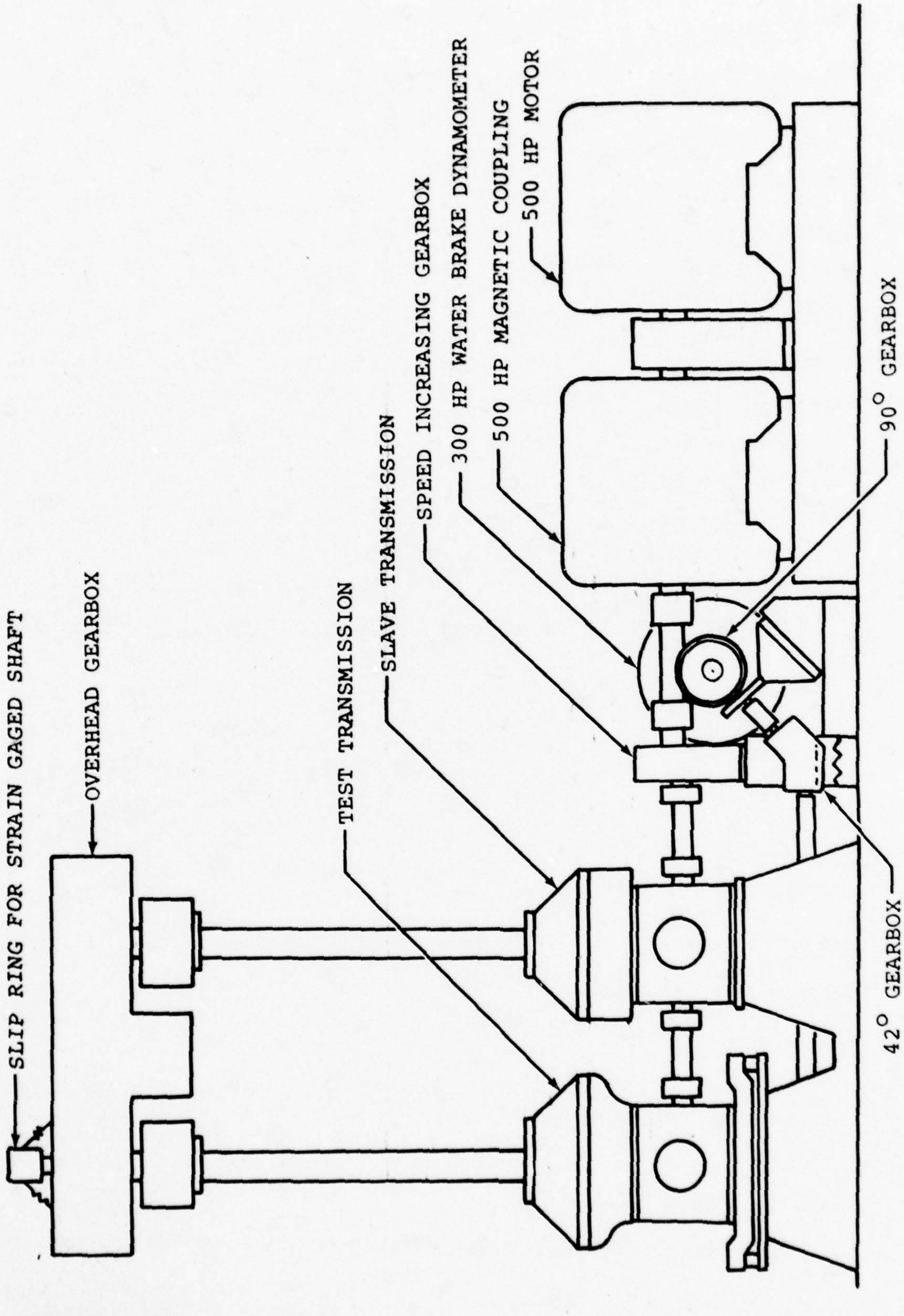

Figure 1. Transmission test stand schematic.

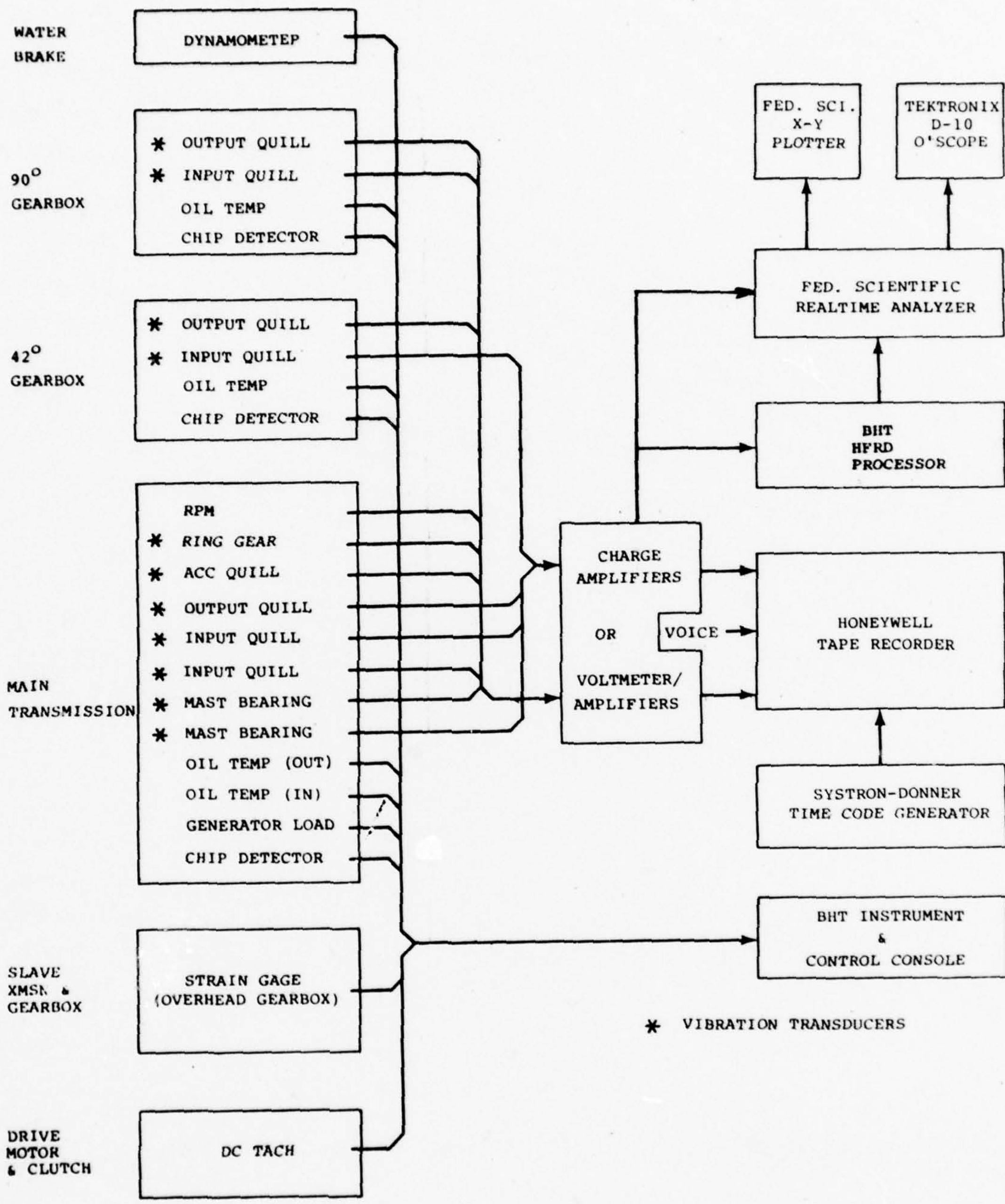

Figure 2. Instrumentation schematic.

Confidence Test (discussed in Section 4.8), detection of the implant part defects was accomplished by means of a High Frequency Resonance Demodulation System which is presented in Section 4.4.

4.2.3 Oil Debris Monitor Installation

The quality of the transmission oil was monitored by a K-West Indicating Screen, a Capacitive Oil Monitor, an Environment One Oil Monitor and a nucleonic oil monitor. An upper mast bearing debris collector was evaluated and three advanced chip detectors were installed for evaluation. The installation of this equipment is illustrated in Figure 3, and the results of the test installations are presented in Sections 4.3.2, 4.3.4, and 4.3.5.

4.2.4 Implant Installation

The implant bearing and gear locations tested are presented in Table I and Figures 4, 5, and 6. The implants were installed per the installation and inspection procedures outlined in the applicable work requirements.

Gear reaction and bearing loads were evaluated from the information contained in References (5) and (6). The loads presented in Table II are calculated for 60% power, where 100% transmission and gearbox power is 1000 and 100 horsepower respectively. The loads are directly related to horsepower at a constant RPM.

Upon installation, the duplex ball bearings are axially preloaded to between 50 and 100 lbs. The gear loading tends to separate the gears, relieving the preload on the inner bearing while the outer bearing absorbs the axial loading. The radial loading is shared equally by each bearing set.

The preload on the main input triplex bearing upon installation is absorbed by the outer bearing. The gear loading relieves the preload while the inner and middle bearing absorb the axial loading. Ideally, the inner and middle bearings share the load equally; however, for design purposes, each bearing is sized for 75% of the axial load.

The failure data available indicated that the member of the bearing set carrying the axial loading is the bearing that will tend to fail. The duplex ball bearing implants were therefore installed with the defect in the outer bearing half, and the input triplex ball bearing was installed with the defect in the innermost bearing. Outer race defects were implanted with the defect oriented in the direction of the reactive radial bearing load as outlined in Table II. Installed orientation of an implant with a roller, ball or inner race defect is immaterial because these are all rotating members.

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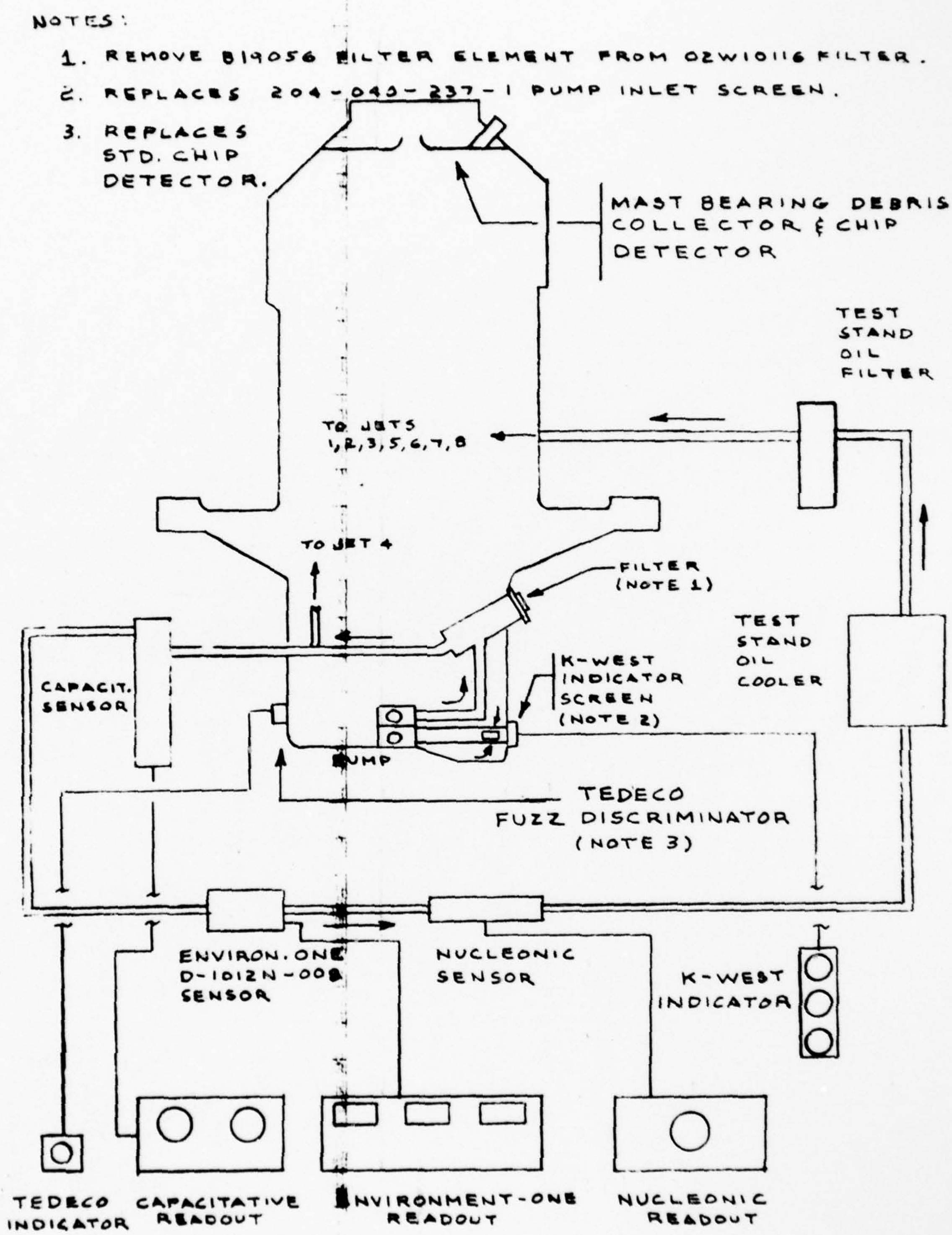

Figure 3. Transmission oil monitor test schematic.

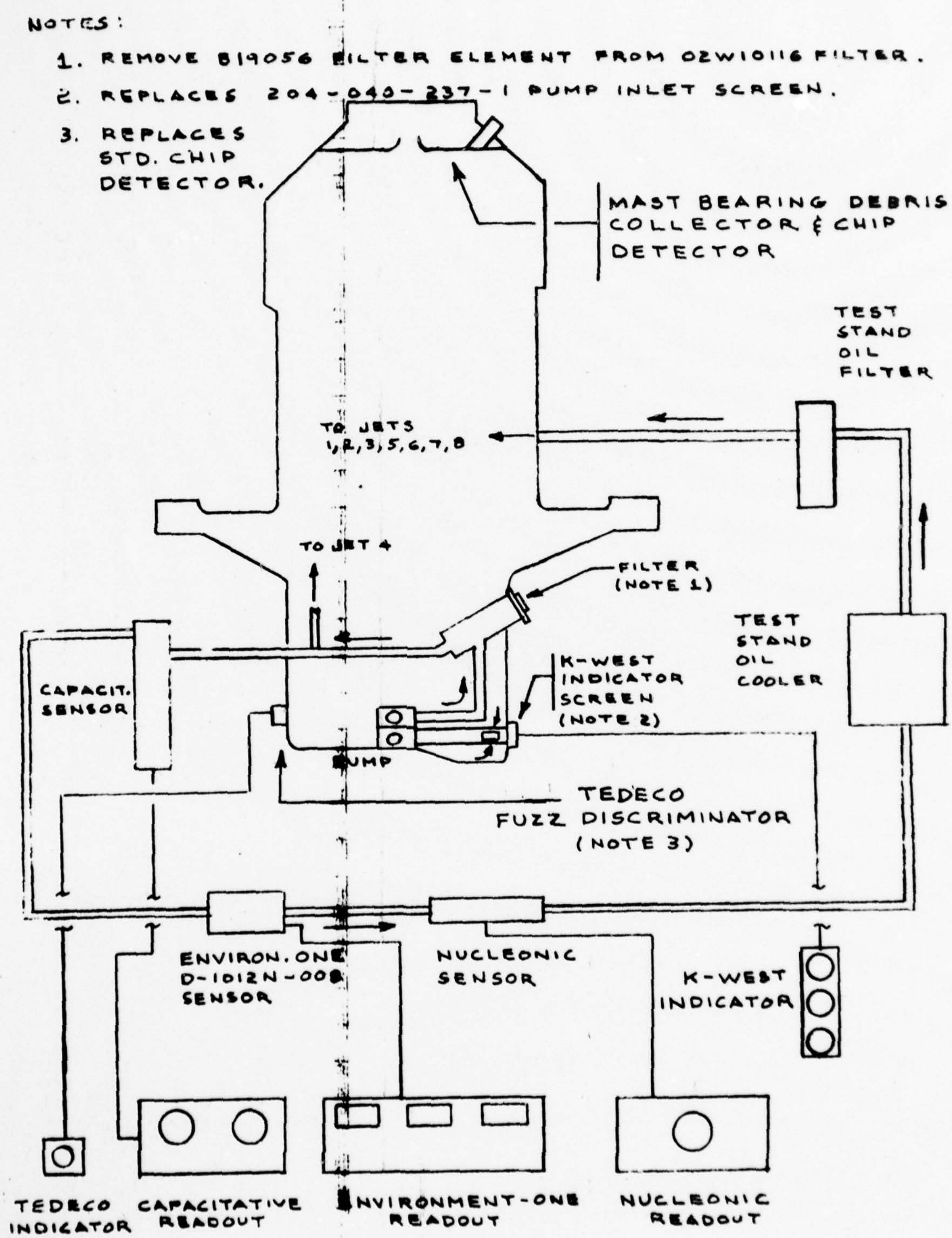

Figure 3. Transmission oil monitor test schematic.

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TABLE I
TRANSMISSION AND GEARBOX
IMPLANT LOCATIONS

Part Number	Description	Location	Figure Ident.
204-040-143-1	Duplex Ball Bearing	42° GB Input Quill	5-20
		42° GB Output Quill	5-25
		T/R Output Quill	4-16
		Offset Quill	4-12
		Sump Quill	4-13
		90° GB Input Quill	6-31
204-040-310-1	Roller Bearing	42° GB Input Quill	5-21
		42° GB Output Quill	5-24
		T/R Output Quill	4-17
		Sump Quill	4-14
204-040-424	Ball Bearing	90° Output Quill	6-26
205-040-246	Triplex Ball Bearing	Transmission Input Quill	4-11
204-040-132	Planet Bearing	Upper Planetary Assy	4-2
		Lower Planetary Assy	4-3
205-040-245	Duplex Ball Bearing	Transmission Quill	4-9
204-040-406	Roller Bearing	90° GB Input Quill	6-29
204-040-407	Roller Bearing	90° GB Output Quill	6-27
204-040-135	Ball Bearing	Transmission Assy	4-5
204-040-136	Ball Bearing	Upper Mast Assy	4-1
204-040-500-9	Gear	42° GB Input Quill	5-22
204-040-500-10	Gear	42° GB Output Quill	5-23

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TABLE I (Cont'd)
TRANSMISSION AND GEARBOX
IMPLANT LOCATIONS

Part Number	Description	Location	Figure Ident.
204-040-401	Gear	90° GB Output Quill	6-28
204-040-400	Gear	90° GB Input Quill	6-30
204-040-700	Gear	Transmission Input Quill	4-10
204-040-701	Gear	Transmission Quill	4-8
204-040-229	Gear	Transmission Lower Sun	4-7
204-040-330	Gear	Transmission Upper Sun	4-5
204-040-331	Gear	Transmission Ring	4-4
204-040-108	Gear	Transmission Planet	4-6
204-040-104	Gear	TR Output Gear	4-18
204-040-103	Gear	Sump Quill	4-15
GC 1669	Oil Pump	Transmission Sump	4-19

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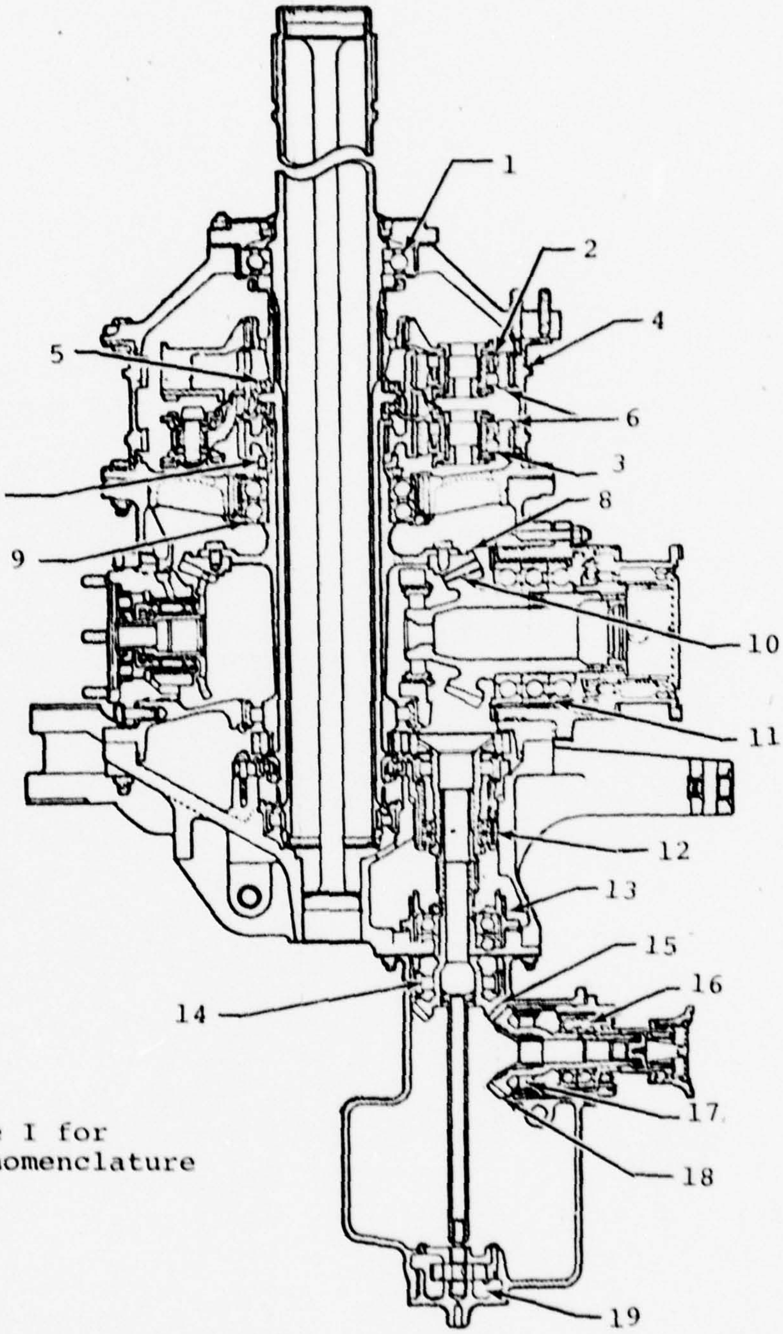

Note:

See Table I for implant nomenclature

Figure 4. Transmission implant locations.

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Note: See Table I for implant nomenclature

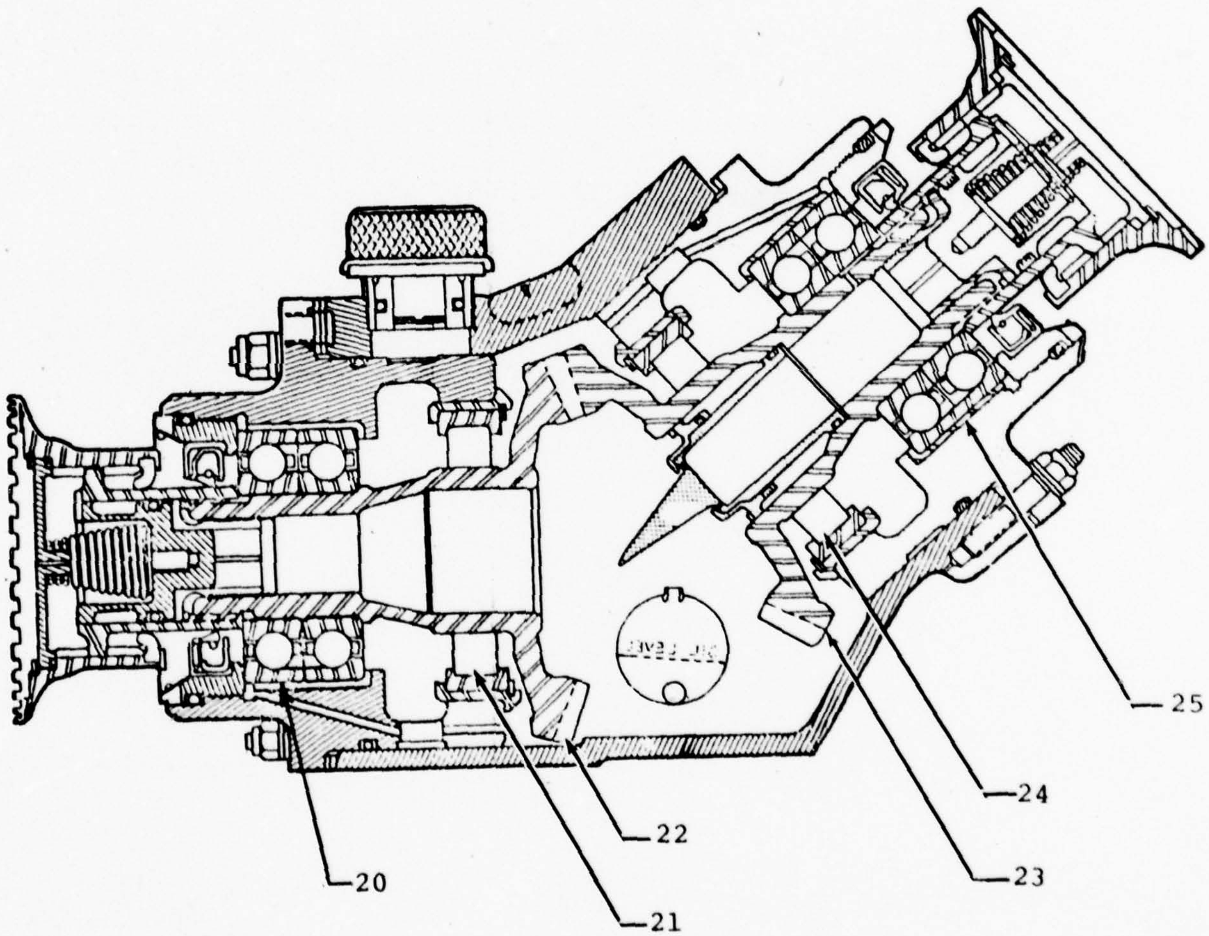
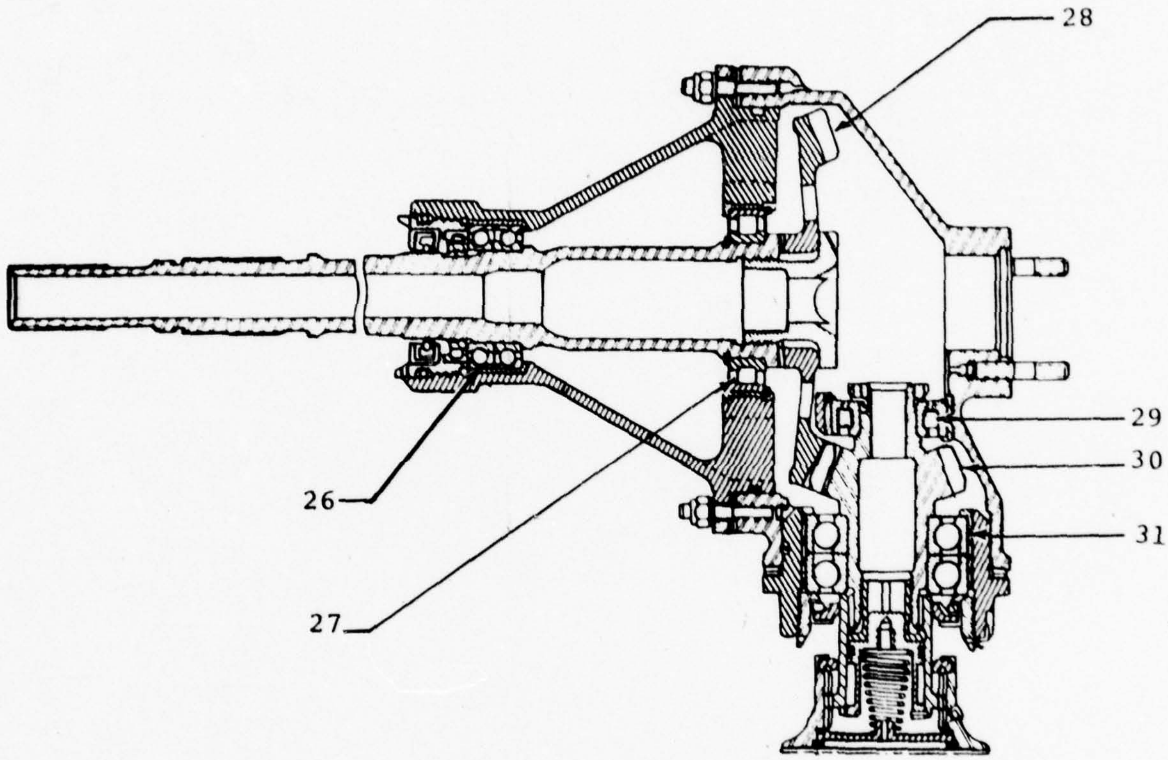


Figure 5. 42-degree gearbox implant locations.



Note: See Table I for implant nomenclature.

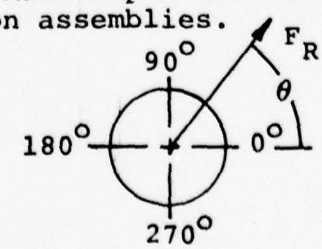
Figure 6. 90-degree gearbox implant locations.

TABLE II
UH-1H BEARING LOADS AND REACTIONS

Bearing P/N	Location	Load - lbs. Axial	Load - lbs. Radial	Direction of Load *Axial	Direction of Load **Radial-θ
204-040-143	42° Input Quill	430	761	Fwd	54°
	42° Output Quill	108	517	Aft	31°
	90° Input Quill	709	595	Fwd	139°
	Offset Quill	Negbl.	732	---	340°
	Sump Input Quill	109	666	Dwn	226°
	T/R Output Quill	533	737	Aft	310°
204-040-310	42° Input Quill	---	1445	---	139°
	42° Output Quill	---	1356	---	216°
	Sump Input Quill		1512	---	41°
	T/R Output Quill		1319	---	150°
204-040-424	90° Output Quill	231	67	Left	160°
204-040-407	90° Output Quill	---	1255	---	Variable
204-040-406	90° Input Quill	---	581	---	58°
205-040-246	Main Input Quill	2270	1680	Aft	231°
205-040-245	Xmsn Quill Assy	289	2470	Up	41°
204-040-136	Mast Assy	5600	1188	Up	Variable
204-040-135	Offset Quill	---	732	---	340°
	Upper Xmsn Assy	Negbl.	---	---	---
204-040-132	Lower Planetary	---	1890	---	Variable
-[illegible]25	Upper Planetary	---	3520	---	Variable

* Axial direction is referenced as installed in aircraft.

** Radial direction is referenced as looking into the 42 and 90 degree gearboxes, main input and tail rotor quill, and down in the transmission assemblies.



4.2.5 Accelerometer Mounting Brackets

External mounting brackets for transmission, 42-degree gearbox, and 90-degree gearbox accelerometers were designed and fabricated by BHT. These brackets met the following requirements:

- Permitted accelerometer installation without drilling, tapping, or otherwise altering the drive train components.
- Utilized existing bolts and studs for attachment.
- Provided for proper sensor orientation and installed clearance.
- Minimized resonance effects.

Bracket design drawings were provided to Airesearch for use on the AIDAPS aircraft, if desired.

4.3 Data Collection - Task III

Drive train test stand data was collected in accordance with the BHT Test Plan, Reference (4). Figure 7 shows the overall data collection schedule. Baseline Data was collected on non-defective transmissions and gearboxes. Diagnostic data was collected with documented discrete defective implanted gears or bearings installed in the transmission and gearboxes. Prognostic data was collected during a Degradation Rate test to determine if a critical drive train part exhibited a repeatable detectable degradation rate which could be used as a prediction of life remaining, and during a Removal Limit Confidence Test to determine the probability of sufficient life remaining after a naturally degraded AIDAPS implant reached the "D" or upper limit "C" category. The parameter data collected is presented in Table III and the test profiles are outlined in Table IV. The prognostic Removal Limit Confidence Test was delayed until the MAIC bearing degradation program to provide fatigue induced bearing defects was completed. The data collection effort and data analysis effort expended in this program are discussed in detail in the following sections of this report.

4.3.1 Vibration Tape Data

Accelerometer, RPM, voice, and time data were recorded at a speed of 30 inches/second in bursts of approximately one minute at the end of each stabilized diagnostic run condition or tenth prognostic cycle per Table IV. A Honeywell Model 96, fourteen-track tape recorder was utilized. A Systron-Donner Model 8150 Time Code Generator was used to generate a modified IRIG B format time code track in terms of Binary Coded Decimal hour, minute, and second.

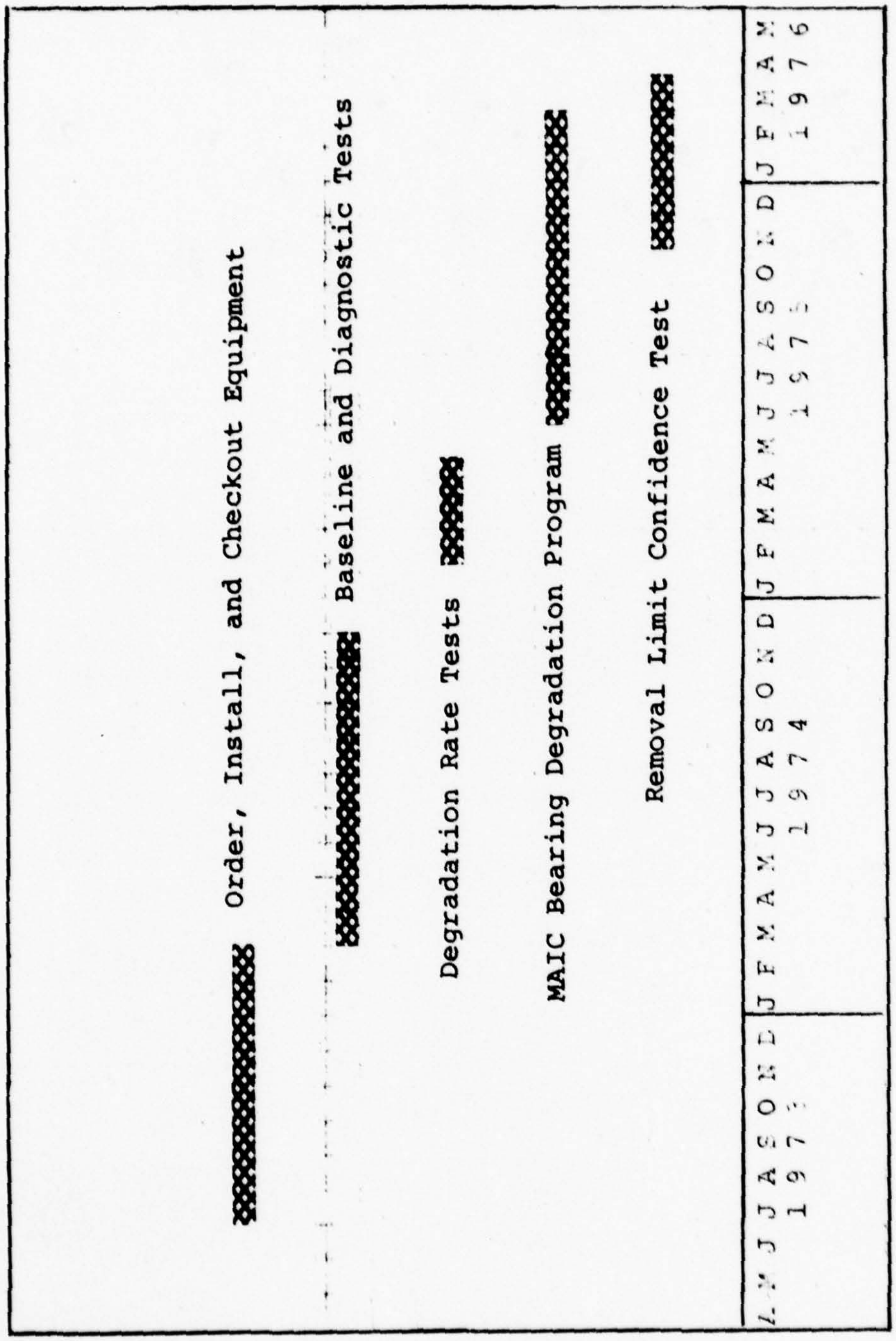


Figure 7. Data collection test cell schedule.

TABLE III
PARAMETER DATA RECORDED

Parameter	Sensor Type	Record
XMSN Mast Torque	Strain Gage	Log Sheets
Tail Rotor Power	Water Brake	Log Sheets
XMSN Input Speed	D.C. Tachometer	Log Sheets
Cell Ambient Temperature	Thermometer	Log Sheets
XMSN Oil In Temperature	C/A Thermocouple	Log Sheets
XMSN Oil Out Temperature	C/A Thermocouple	Log Sheets
42° G/B Oil Temperature	C/A Thermocouple	Log Sheets
90° G/B Oil Temperature	C/A Thermocouple	Log Sheets
XMSN Oil In Pressure	Pressure Gage	Log Sheets
XMSN Oil Out Pressure	Pressure Gage	Log Sheets
ΔP Capacitive Monitor	Pressure Gage	Log Sheets
ΔP Env-1 Monitor	Pressure Gage	Log Sheets
ΔP Nucleonic Monitor	Pressure Gage	Log Sheets
Hydraulic Pump Output Pressure	Pressure Gage	Log Sheets
Generator Load	Ammeter	Log Sheets
XMSN Mast Bearing Vibrations	Vibration Transducer	Tape Recorder
XMSN Input Quill Vibrations	Vibration Transducer	Tape Recorder
XMSN Mast Bearing Vibrations	Vibration Transducer	Tape Recorder
XMSN Input Quill Vibrations	Vibration Transducer	Tape Recorder
XMSN T/R Output Quill Vibrations	Vibration Transducer	Tape Recorder
42° G/B Input Quill Vibrations	Vibration Transducer	Tape Recorder

TABLE III (Continued)

Parameter	Sensor Type	Record
42° G/B Output Quill Vibrations	Vibration Transducer	Tape Recorder
90° G/B Input Quill Vibrations	Vibration Transducer	Tape Recorder
XMSN Accessory Quill Vibrations	Vibration Transducer	Tape Recorder
XMSN Ring Gear Case Vibrations	Vibration Transducer	Tape Recorder
XMSN Chips	Magnetic Chip Detector	Log Sheets
42° Chips	Magnetic Chip Detector	Log Sheets
90° Chips	Magnetic Chip Detector	Log Sheets
XMSN Chips	K-West Indicating Screen	Log Sheets
XMSN Oil Contamination	Franklin Capacitive Indicator	Log Sheets
XMSN Oil Contamination	Environment One Light Beam	Log Sheets
XMSN Oil Contamination	Nucleonic X-Ray Flourescence	Log Sheets
XMSN RPM Signal Generator	44 Tooth Wheel	Tape Recorder

TABLE IV. AIDAPS POWER TRAIN CELL TEST PROFILES

A. Baseline and Diagnostic Tests

STEP	TIME	TRANSMISSION INPUT			MAST OUTPUT			TAIL ROTOR DRIVE			GENERATOR		HYDRAULIC PUMP	
	(Minimum) Minutes	RPM	Torque in-lb	H.P. (Approx)	RPM	Torque in-lb	H.P.	RPM	Torque in-lb	H.P.	Amps @ 28 VDC	H.P.	Output Pressure (No Flow) PSIG	H.P. (Approx)
1	No Load Condition - Gradually increase input speed to 6600 RPM. Stabilize XMSN oil inlet temperature @ 70-80°C (158-176°F)													
	As Req'd	6600	Min.		324	Min		4300	Min		0	0	0	0
2	Light Weight, Minimum Power Flight Condition - Maximum RPM													
	5	6600	2863	300	324	52858 (13.2%)	271	4300	264	18	240	10	1000	1
3	Heavy Weight Minimum Power Flight Condition - Maximum RPM													
	5	6600	4773	500	324	89526 (22.4%)	459	4300	440	30	240	10	1000	1
4	Light Weight Hover Condition													
	5	6600	5727	600	324	104350 (26.0%)	535	4300	791	54	240	10	1000	1
5	Light Weight Cruise Condition - Maximum RPM													
	5	6600	6682	700	324	129510 (32.4%)	664	4300	366	25	240	10	1000	1
6	Heavy Weight V Maximum Condition - Maximum RPM													
	5	6600	8591	900	324	168130 (42.0%)	862	4300	396	27	240	10	1000	1
7	Maximum Power Hover Condition													
	5	6600	10500	1100	324	192900 (48.2%)	989	4300	1465	100	240	10	1000	1
8	Light Weight, Minimum Power Flight Condition - Cruise RPM													
	5	6400	2953	300	314	54546 (13.6%)	271	4170	272	18	240	10	1000	1
9	Heavy Weight Minimum Power Flight Condition - Cruise RPM													
	5	6400	4922	500	314	92387 (23.1%)	459	4170	453	30	240	10	1000	1
10	Light Weight Cruise Condition - Cruise RPM													
	5	6400	6891	700	314	133649 (33.4%)	664	4170	378	25	240	10	1000	1
11	Heavy Weight V Maximum Condition - Cruise RPM													
	5	6400	8859	900	314	173502 (43.3%)	862	4170	408	27	240	10	1000	1

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TABLE IV. (Cont'd)

B. Prognostic Tests - Degradation Rate Runs

STEP	TIME	XMSN INPUT			MAST OUTPUT				TAIL ROTOR DRIVE		
		RPM	Torque in-lb	H.P. (Approx)	RPM	Torque in-lb	Torque %	H.P.	RPM	Torque in-lb	H.P.
1	3 min	6600	10500	1100	324	192305	48	989	4300	1465	100
2	27 min	6600	8591	900	324	167611	42	862	4300	396	32

NOTE:

1. During Step 1, make 15 second tail rotor power transient to 130 HP and return
2. Maintain generator load at 240 amps (approx. 10 HP)
3. Maintain hydraulic pump load at 1000 psig, no flow (approx. 1 HP)
4. 100% test stand mast torque = 400,000 in-lb
5. Maintain mast loads at 8600 lb. lift, 480 lb. shear

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TABLE IV. (Cont'd)

C. Prognostic Tests - Removal Limit Confidence Runs

STEP	TIME	XMSN INPUT				MAST OUTPUT			TAIL ROTOR DRIVE		
		RPM	Torque in-lb	H.P. (Approx)	RPM	Torque in-lb	Torque %	H.P.	RPM	Torque in-lb	H.P.
1	6 min	6600	10500	1100	324	192305	48	989	4300	1465	100
2	54 min	6600	8591	900	324	167611	42	862	4300	396	32

NOTE:

1. 100% test stand mast torque = 400,000 in-lb
2. Maintain the following loads:
   Generator: 240 amps (Approx. 10 H.P.)
   Hydraulic pump pressure (no flow): 1000 psig (Approx. 1 H.P.)
   Mast: 8600 lb. lift, 480 lb. shear
3. During Step 1, make 30 second tail rotor power sweep to 130 H.P. and return
4. Tape record data as follows:
   (a) 150 ft. leader at beginning of tape
   (b) Initial calibration steps
   (c) During 1st cycle, record 1 minute (150 feet) of Step 1 (include power sweep) and 1 minute of Step 2. Repeat every 10th cycle.
   (d) Final calibration steps
5. Fill in data sheet once per step. Log all starts, stops, and unusual events
6. Take oil analysis (SOAP) sample once per day (Xmsn only).
7. Shutdown for inspection every 100 hours

The tape recorder track assignments, parameters recorded, accelerometers utilized and record mode are outlined in Table V. The accelerometer types and record mode changes were specified through Run 792 by the Airesearch Manufacturing Company in order to complement and support their flight test data collection effort at Ft. Rucker. The accelerometer types and changes during the Removal Limit Test were dictated by the requirements of the High Frequency Resonance Demodulation data reduction technique. Table VI summarizes the data collection runs. Accelerometer locations are shown by Figures 8 and 9.

4.3.2 Oil Monitor Test Data

The oil condition monitoring devices were installed in the AIDAPS transmission test stand in accordance with Section 4.2 and operated as subsequently described in conjunction with the planned transmission tests. The installation is shown schematically in Figure 3. The screen discs were removed from the transmission internal oil filter in order to permit particles to flow through to the oil monitors downstream. The characteristics of the monitors determined their relative position in the flow path. The K-West screen was placed first because it traps relatively large particles, and passes those which are less than approximately 1000 microns. The capacitative monitor contains a screen which removes particles larger than 50 microns. The Environment One and nucleonic monitors do not trap particles. Both were installed downstream of the coarse filter in the capacitative monitor in order to prevent internal damage or stoppage by debris. To maintain the order of decreasing particle size detection, the Environment One unit, which senses particles in suspension, was placed ahead of the nucleonic, which senses metals in solution. The oil then flowed through the test stand oil cooler and filter before entering the transmission lubrication system.

4.3.2.1 K-West Indicating Screen

The K-West Model 533DA screen is shown in Figure 10. The screen is constructed of conductive circumferential wires, separated by longitudinal non-conductive strands. A conductive particle across any two adjacent wires in the grid completes a circuit which activates an indicating light. The AIDAPS screen was wired to provide three indicating zones. Assuming that a particle flows to the end of the screen before coming to rest across two conductors, the first particle trapped would illuminate the "10 percent" zone light. Further particles would have no effect until the zone was filled, then the "20 percent" zone light would come on, and finally the "over 30 percent" light. Ideally, the screen would be installed in a scavenge line. In the UH-1 transmission, the only possible way to install the screen was to design it to replace the standard oil pump inlet screen. The physical constraints of this installation necessitated a non-optimum screen design.

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TABLE V
TAPE RECORDER TRACK ASSIGNMENTS

Track	Parameter	Vibration Transducer	Record Mode
	A. Runs 1 through 11		
1	Mast Bearing	B&K Model 4343	FM
2	Voice		Direct
3	Input Quill	B&K Model 4343	FM
4	RPM		Direct
5	Mast Bearing	MB Model 11	FM
6	Time Code		Direct
7	Input Quill	MB Model 14	FM
8	Tail Rotor Quill	Endevco Model 6222M2	FM
9	42° Input	Endevco Model 6222M2	FM
10	42° Output	CRL Model 1111-1	FM
11	90° Input	CRL Model 1111-1	FM
12	90° Output	CRL Model 1111-1	FM
13	Hydraulic Pump Quill	CRL Model 1111-1	FM
14	Ring Gear	CRL Model 1111-1	FM
	B. Runs 12 through 58		
1	Mast Bearing	B&K Model 4343	FM
2	Voice		Direct
3	Input Quill	B&K Model 4343	FM
4	RPM		Direct
5	Mast Bearing	MB Model 11	FM
6	Time Code		Direct
7	Input Quill	MB Model 14	FM
8	Tail Rotor Quill	MB Model 14	Direct
9	42° Output	CRL Model 1111-1	FM
10	42° Input	Endevco Model 6222 M26	Direct
11	90° Input	CRL Model 1111-1	FM
12	90° Output	CRL Model 1111-1	FM
13	Hydraulic Pump Quill	CRL Model 1111-1	FM
14	Ring Gear	CRL Model 1111-1	FM
	C. Runs 59 through 458		
1	Mast Bearing	B&K Model 4343	FM
2	Input Quill	B&K Model 4343	FM
3	Mast Bearing	MB Model 11	FM
4	Input Quill	Model 14	FM
5	Tail Rotor Quill	Endevco Model 6222M26	Direct
6	42° Input	Endevco Model 6222M26	Direct
7	42° Output	CRL Model 1111-1	FM
8	90° Input	CRL Model 1111-1	FM
9	90° Output	CRL Model 1111-1	FM

TABLE V (Cont'd)
TAPE RECORDER TRACK ASSIGNMENTS

Track	Parameter	Vibration Transducer	Record Mode
	C. Runs 59 through 58 (Cont'd)		
10	Hydraulic Pump Quill	CRL Model 1111-1	FM
11	Ring Gear	CRL Model 1111-1	FM
12	RPM		Direct
13	Voice		Direct
14	Time Code		Direct
	D. Runs 459 through 491		
8	90^{o} Input	CRL Model 1111-1	FM
9	90^{o} Output	CRL Model 1111-1	FM
12	RPM		Direct
13	Voice		Direct
14	Time		Direct
	E. Runs 492 through 527		
1	Mast Bearing	B&K Model 4343	FM
2	Input Quill	B&K Model 4343	FM
3	Mast Bearing	MB Model 11	FM
4	Input Quill	MB Model 14	FM
5	Tail Rotor Quill	Endevco Model 6222M26	Direct
10	Hydraulic Pump Quill	CRL Model 1111-1	FM
11	Ring Gear	CRL Model 1111-1	FM
12	RPM		Direct
13	Voice		Direct
14	Time		Direct
	F. Runs 528 through 792 120 Hour Degradation Rate Test		
1	Mast Bearing	B&K Model 4343	FM
2	Input Quill	B&K Model 4343	FM
3	(Not Used)	B&K Model 4343	FM
4	(Not Used)	B&K Model 4343	FM
5	Tail Rotor Quill	Endevco Model 6222M26	Direct
6	42^{o} Input	Endevco Model 6222M26	Direct
7	42^{o} Output	CRL Model 1111-1	FM
8	90^{o} Input	CRL Model 1111-1	FM
9	90^{o} Input	CRL Model 1111-1	FM
10	Hydraulic Pump Quill	CRL Model 1111-1	FM

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TABLE V (Concluded)
TAPE RECORDER TRACK ASSIGNMENTS

Track	Parameter	Vibration Transducer	Record Mode
	F. Runs 528 through 792 (Cont'd)		
11	Ring Gear	CRL Model 1111-1	FM
12	RPM		Direct
13	Voice		-
14	Time Code		Direct
	G. Runs 793 through 965 Removal Limit Confidence Test		
1	(Not Used)		
2	Upper Mast Bearing	B&K Model 8309	Direct
3	Xmsn Input Quill	B&K Model 4344	Direct
4	Xmsn Ring Gear	B&K Model 8309	Direct
5	Tail Rotor Quill	B&K Model 8309	Direct
6	42° Input	B&K Model 4344	Direct
7	42° Output	B&K Model 4344	Direct
8	90° Input	B&K Model 4344	Direct
9	90° Output	B&K Model 4344	Direct
10	(Not Used)	B&K Model 4344	Direct
11	(Not Used)	B&K Model 4344	Direct
12	RPM		Direct
13	Voice		-
14	Time Code		Direct
	H. Runs 966 and Subsequent		
1	(Not Used)		
2	Upper Mast Bearing	B&K Model 4344	Direct
3	Xmsn Input Quill	B&K Model 4344	Direct
4	Xmsn Ring Gear	B&K Model 4344	Direct
5	Tail Rotor Quill	B&K Model 4344	Direct
6	42° Input	B&K Model 4344	Direct
7	42° Output	B&K Model 4344	Direct
8	90° Input	B&K Model 4344	Direct
9	90° Output	B&K Model 4344	Direct
10	(Not Used)	B&K Model 4344	Direct
11	(Not Used)	B&K Model 4344	Direct
12	RPM		Direct
13	Voice		Direct
14	Time Code		Direct

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TABLE VI. AIDAPS TEST CELL RUN SUMMARY

DATE	RUN	MASTER LOG NO.	TAPE REEL S/N	AIDAPS TAPE REEL BHC #	TYPE RUN	COMPONENT	IMPLANT
2/25/74	-	-	3182	001	Test Tape		
2/26/74	1-11	001	3198	002	Baseline	42^{o} Gearbox	-
3/ 5/74	12-22	002	3198	002	Baseline	42^{o} Gearbox	-
3/ 6/74	23-33	003	0506	003	Baseline	42^{o} Gearbox	-
3/ 7/74	34-44	003	0506	003	Baseline	42^{o} Gearbox	-
3/ 8/74	45-58	004	0505A	004	Diagnostic & Validation	42^{o} Gearbox	BHC-001
3/19/74	59-69	005	0516	005	Diagnostic & Validation	42^{o} Gearbox	BHC-002
3/19/74	70-80	005	0516	005	Diagnostic & Validation	42^{o} Gearbox	BHC-003
3/21/74	81-91	006	565A	006	Baseline	42^{o} Gearbox	-
3/25/74	92-103	007	579A	007	Baseline	42^{o} Gearbox	-
3/26/74	103-113	008	580A	008	Diagnostic & Validation	42^{o} Gearbox	BHC-003
3/27/74	114-124	003	599A	009	Diagnostic & Validation	42^{o} Gearbox	BHC-004
3/30/74	125-135	010	599A	010	Diagnostic & Validation	42^{o} Gearbox	BHC-005
4/ 1/74	136-149	011	601A	011	Diagnostic & Validation	42^{o} Gearbox	BHC-006
4/ 5/74	150-165	012	600A	012	Diagnostic & Validation	42^{o} Gearbox	BHC-006
4/ 8/74	166-181	013	632A	013	Baseline	42^{o} Gearbox	-
5/ 9/74	182-199	014	634A	014	Baseline	90^{o} Gearbox	-
5/ 9/74	200-217	015	1233	015	Baseline	90^{o} Gearbox	-
5/25/74	218-235	016	1373	016	Diagnostic & Validation	90^{o} Gearbox	BHC-008
6/ 3/74	236-245	017	1825	017	Diagnostic & Validation	42^{o} Gearbox	BHC-007
6/ 4/74	246-255	018	1813	018	Baseline	42^{o} Gearbox	-
6/ 5/74	256-265	018	1813	018	Baseline	42^{o} Gearbox	-
6/ 5/74	266-275	019	841	019	Baseline	42^{o} Gearbox	-
6/ 6/74	276-285	019	841	019	Diagnostic & Validation	42^{o} Gearbox	BHC-007
6/ 7/74	286-295	020	782	020	Diagnostic & Validation	42^{o} Gearbox	BHC-007
6/ 7/74	296-205	020	782	020	Diagnostic & Validation	42^{o} Gearbox	BHC-007
6/ 8/74	306-315	021	333	021	Diagnostic & Validation	42^{o} Gearbox	BHC-007
6/ 8/74	316-325	021	333	021	Diagnostic & Validation	42^{o} Gearbox	BHC-007
6/ 8/74	326-335	022	685	022	Diagnostic & Validation	42^{o} Gearbox	BHC-009
6/10/74	336-345	022	685	022	Diagnostic & Validation	42^{o} Gearbox	BHC-010
6/11/74	346-355	023	663	023	Diagnostic & Validation	42^{o} Gearbox	BHC-011
6/12/74	356-365	023	663	023	Diagnostic & Validation	42^{o} Gearbox	BHC-012
6/13/74	366-373	024	2032	024	Diagnostic & Validation	42^{o} Gearbox	BHC-013
6/13/74	376-385	024	2032	024	Diagnostic & Validation	42^{o} Gearbox	BHC-014

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TABLE VI. AIDAPS TEST CELL RUN SUMMARY (Cont'd)

DATE	RUN	MASTER LOG NO.	TAPE REEL S/N	AIDAPS TAPE REEL BHC #	TYPE RUN	COMPONENT	IMPLANT
6/14/74	286-395	025	2766	025	Diagnostic & Validation	42° Gearbox	BHC-015
6/15/74	396-405	026	2482	026	Diagnostic & Validation	42° Gearbox	BHC-016, 017
6/19/74	406-415	027	322	027	Diagnostic & Validation	42° Gearbox	BHC-018
6/21/74	416-425	027	322	027	Diagnostic & Validation	42° Gearbox	BHC-019
6/22/74	426-438	028	314	028	Diagnostic & Validation	42° Gearbox	BHC-016, 017
6/24/74	439-448	029	311	029	Diagnostic & Validation	42° Gearbox	BHC-020
6/24/74	449-458	029	311	029	Diagnostic & Validation	42° Gearbox	BHC-021
9/ 4/74	459-471	030	420	030	Diagnostic & Validation	90° Gearbox	BHC-025 to 030
9/ 4/74	472-478	030	420	030	Diagnostic & Validation	90° Gearbox	BHC 031 to 035
9/ 7/74	479-491	031	418	031	Diagnostic & Validation	90° Gearbox	BHC-031 to 035
10/3/74	492-509	032	1182	032	Diagnostic & Validation	Transmission	BHC-044, 046, 047, 067, to 070, 072 to 075
10/11/74	510-527	033	1184	033	Diagnostic & Validation	Transmission	BHC-048, 049, 051, 076 to 083
3/26/75 to 4/ 2/75	528-614	034	1305	034	Failure Progression Rate	Transmission 42° Gearbox 90° Gearbox	BHC-105 BHC-001 BHC-101/102
4/ 3/75 to 4/11/75	615-702	035	1285 1287	035 036	Failure Progression Rate	Transmission 42° Gearbox 90° Gearbox	BHC-105 BHC-001 BHC-101/102
4/14/75 to 4/17/74	703-792	036	416 1233	037 038	Failure Progress Rate	Transmission 42° Gearbox 90° Gearbox	BHC-105 BHC-001 BHC-101/102
1/13/76 to 2/ 2/76	793-965	037	3303 3402 3301 3306 3699	039 040 041 042 - 043	Removal Limit Confidence	Transmission 42° Gearbox 90° Gearbox	BHC-008,038,039,068,079, 115,116,123,126,130,131 MAIC-003,004 BHC-001,104,110,127,128 MAIC-002,007,008 BHC-113,114 MAIC-001,005,006
2/17/76 to 3/ 3/76	966-1081	038	3300 3283 3262	044 045 046	Removal Limit Confidence	Transmission 42° Gearbox 90° Gearbox	BHC-036,037,050,071,083, 103,104,124 MAIC-007,008,013,014,015, 017,018 BHC-111,112 MAIC-009,010,011,021 BHC-101,102 MAIC-012,016,019,020

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TABLE VI. AIDAPS TEST CELL RUN SUMMARY (Concluded)

DATE	RUN	MASTER LOG NO.	TAPE REEL S/N	AIDAPS TAPE REEL BHC #	TYPE RUN	COMPONENT	IMPLANT
3/12/76 to 3/22/76	1082-1209	039	3624 3700 3303	047 048 049	Removal Limit Confidence	Transmission	BHC-132,138,139 MAIC-009,010,011,012, 021,024,025
						42° Gearbox	BHC-134,135 MAIC-007,008,027,028
						90° Gearbox	BHC-033,034,136,137 MAIC-003,006,023,026, 030,031
3/30/76	1210-1219	040	1291 597	050 051	Removal Limit Confidence		Baseline (No Implants)

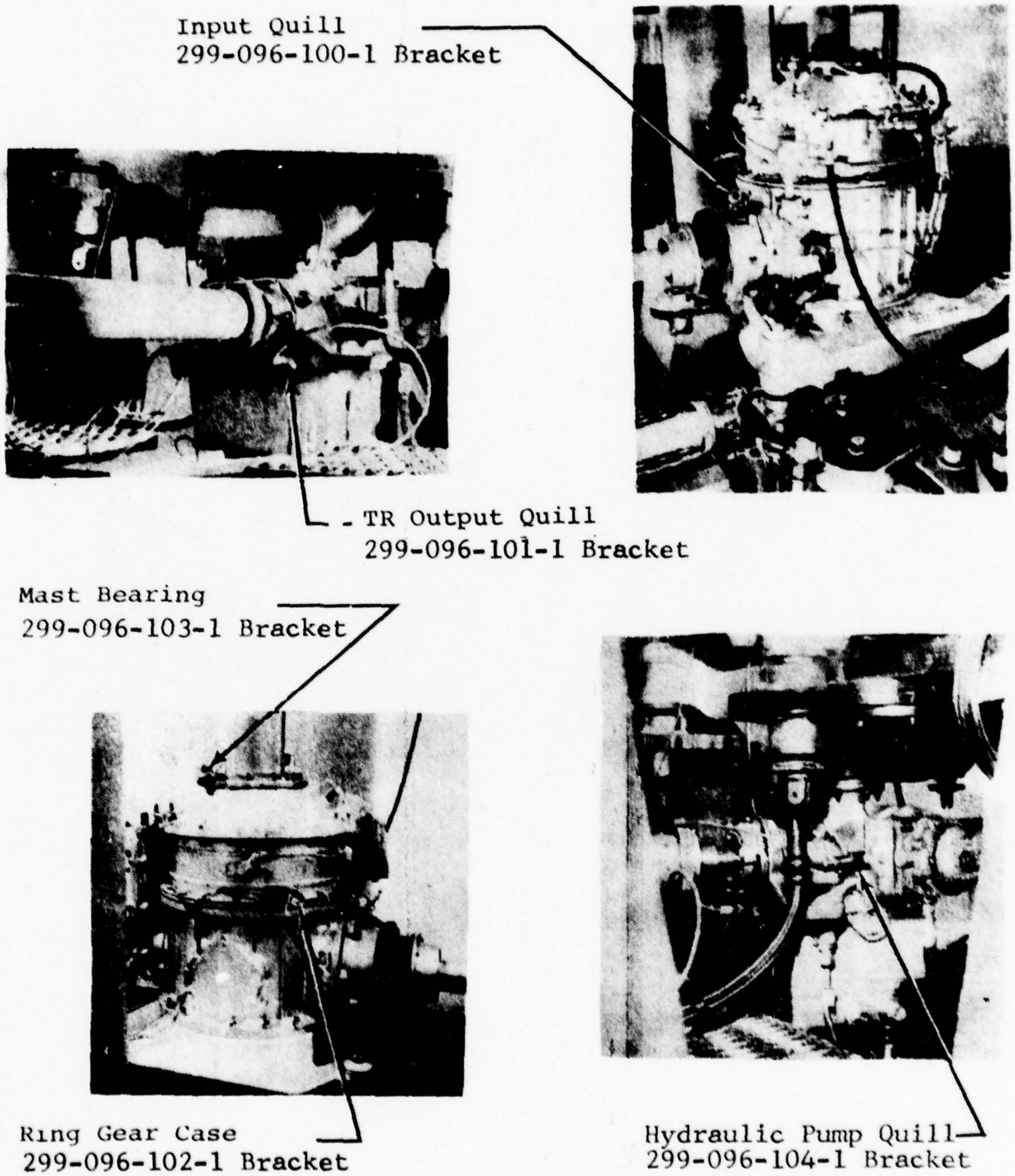

Figure 8. Transmission vibration transducer locations.

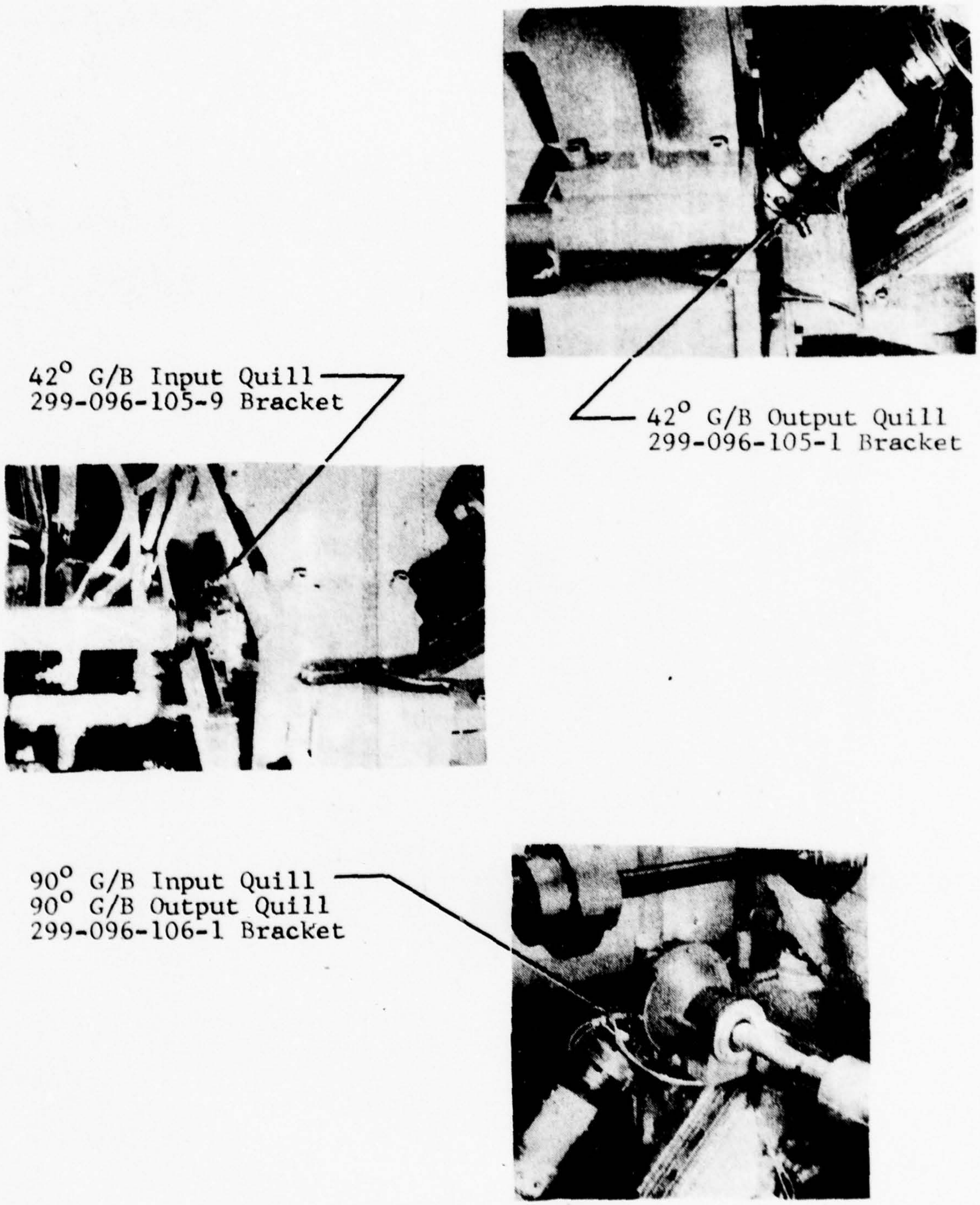

Figure 9. Gearbox vibration transducer locations.

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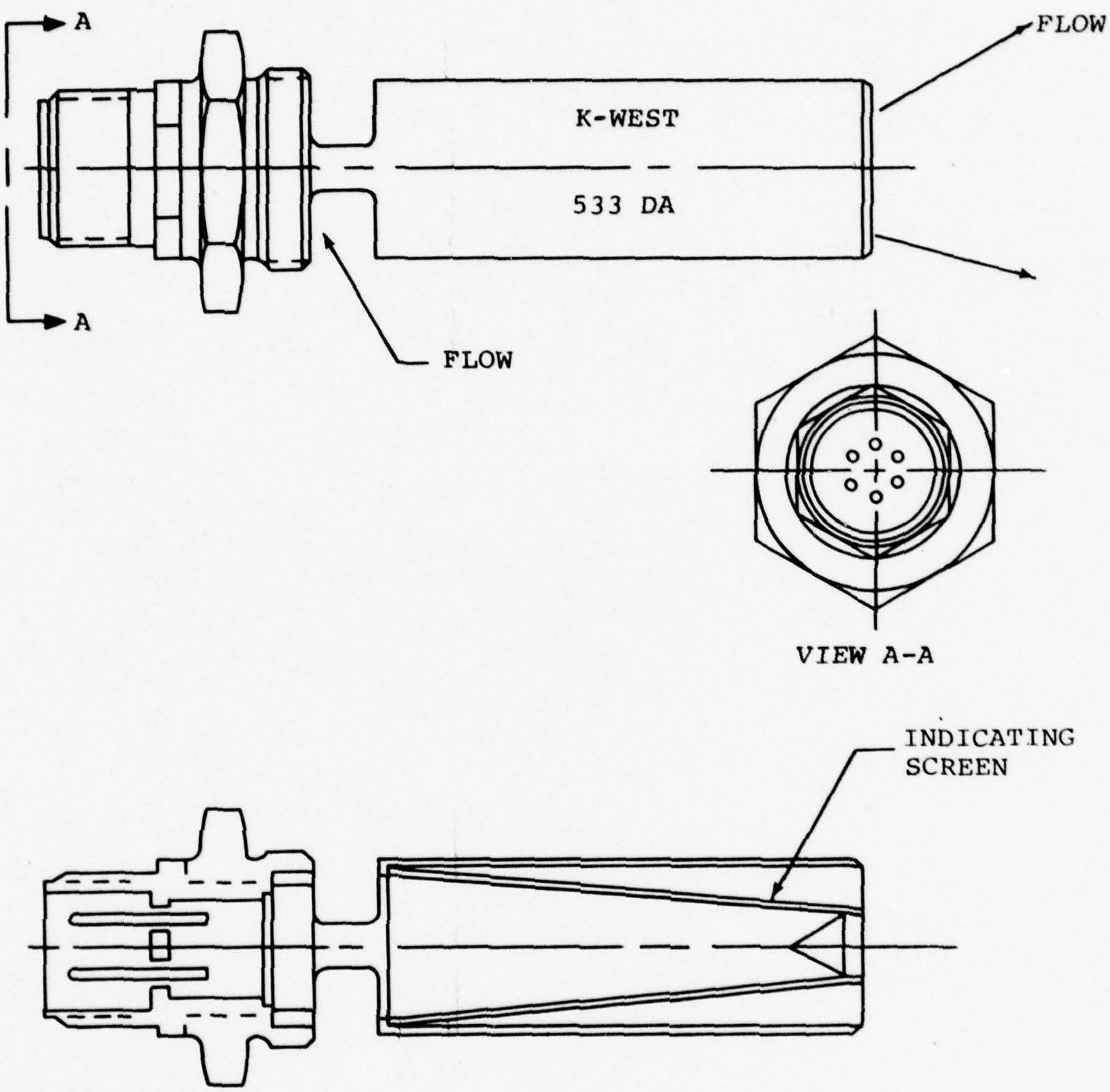

Figure 10. K-West indicating screen.

In operation, the screen did indicate the presence of debris. However, the debris-collection did not progress through the zones as expected. Particles appeared to lodge in the screen at random locations, resulting in random actuations of the three zone indicator lights. When the presence of debris was indicated, it was extremely difficult to clean the screen and clear the actuation. Finally, during the Removal Limit Confidence Tests, the screen became obstructed by debris from a failing bearing, with consequent loss of transmission oil pressure. Most of these problems were due to the design of this particular screen, and would not necessarily be the case with a more conventional installation.

It is concluded that the K-West screen provides a simple, positive means of indicating the presence of relatively large conductive particles in the oil. As compared to a chip detector, it is not subject to "fuzzy" buildup, and is not restricted to magnetic material. When installed in a lubrication system, the screen must be easily accessible for cleaning and must have bypass provisions in the event the debris from a major failure clogs the screen. If indicating zones are used, there may be some value in knowing the number of zones activated; however, this should not be interpreted as "percent full." Three particles in one zone, or one particle in each of three zones, appears equally probable. The K-West for use as a pump inlet screen is not recommended.

4.3.2.2 Capacitative Oil Debris Monitor

An experimental Capacitative Oil Debris Monitor was provided by USAAMRDL for evaluation. This device was designed and constructed by Franklin Institute Research Laboratories, Philadelphia, Pennsylvania, under contract to USAAMRDL. The monitor sensor is shown schematically by Figure 11, and is described in detail by Reference (7). Debris removed by an internal screen falls into the gap between two plates of a capacitor, thus changing its dialectric characteristics, and therefore capacitance, in a manner which is proportional to the amount of debris collected. The capacitance of the measurement capacitor is compared to that of a reference capacitor (which sees only filtered oil) by means of an electronic readout unit.

During most of the tests, not enough debris was generated to cause any appreciable actuation of the indicators. The original screen assembly was found to be too fragile, and after several local repairs, finally failed completely due to inadvertent reversal of flow through the unit. A reinforced replacement screen was provided by Franklin Labs. It was anticipated that the Removal Limit Tests would generate enough debris to exercise the unit. However, during these tests, there were still no

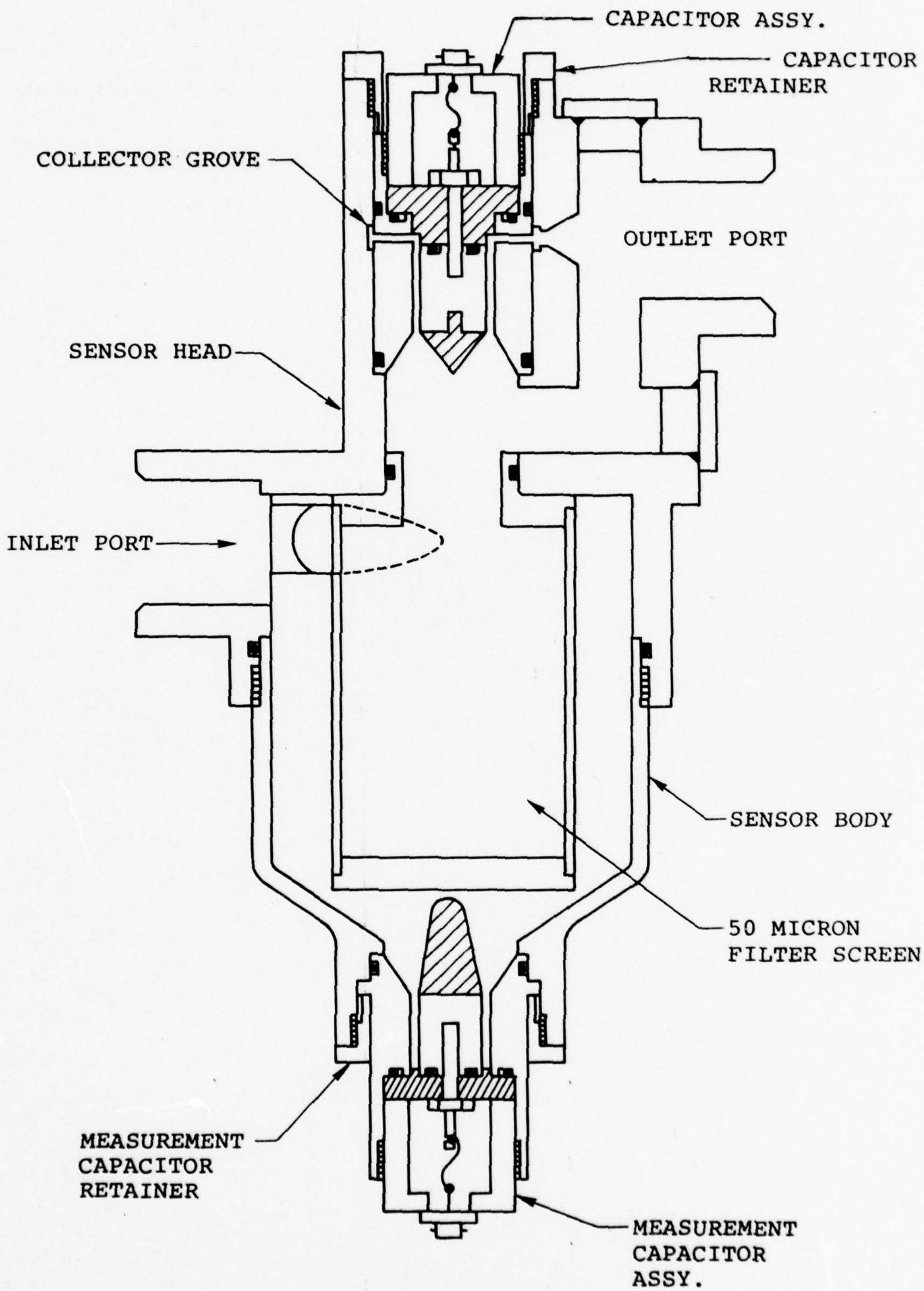

Figure 11. Capacitive oil debris monitor.

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indications. The readout unit was checked by the BHT Instrumentation Laboratory and found to be inoperative. Trouble-shooting was pursued only to the point of determining that the unit was not readily repairable locally. By this time the test program was near completion and there was not time for a vendor repair. Although the screen is supposed to be self-cleaning by means of a swirl imparted to the entering oil, this action was not completely successful and the screen again collapsed due to debris buildup.

It is concluded that the sensor and related readout electronics are too large, heavy, and complex for an aircraft application. The equipment should be suitable, however, for ground based equipment. Pressure drop across the unit is undesirably high, and would require a bypass for cold start operation. It is realized that the unit provided was designed only to prove the concept, and that the objections noted could be reduced by a development effort. Also, due to the various circumstances noted, the AIDAPS tests did not provide the desired extent of evaluation.

4.3.2.3 Environment One Equipment Condition Monitor

An Environment One sensor and readout unit was procured from the Environment One Corporation, Schenectady, New York, in accordance with the Statement of Work. The sensor unit is shown schematically by Figure 12. This unit utilizes a beam of light and two photoelectric sensors. The light beam shines through the oil as it flows through the sensor. Scatter and attenuation of the light beam due to particles in the oil are measured by the photoelectric cells, and indicated by meters on the readout unit. A rotating vane within the unit provides a signal which is proportional to oil flow rate, which also is indicated on the readout unit. The unit does not remove contaminants from the oil. It is intended to detect the presence of dust-like particles suspended in the oil, and should not be located where large debris may be introduced.

The equipment operated satisfactorily during the AIDAPS baseline and diagnostic runs; however, as previously noted, these runs produced very little debris. On 11 June 1974, BHT was directed by USAAVSCOM to send the equipment to Avco Lycoming for use during AIDAPS engine prognostic tests. It was to be returned to BHT prior to initiation of the Removal Limit Tests. However, the sensor unit was apparently lost at Lycoming, and therefore was not available for further BHT evaluation.

The Environment One is a production device, which gives it a considerable advantage over the other one-of-a-kind units. The sensor is small, light, easily installed, and doesn't leak. Pressure drop is acceptably low, and the readout unit is simple. There may be a problem in relating the scatter and attenuation readings to required maintenance actions. In this regard, the

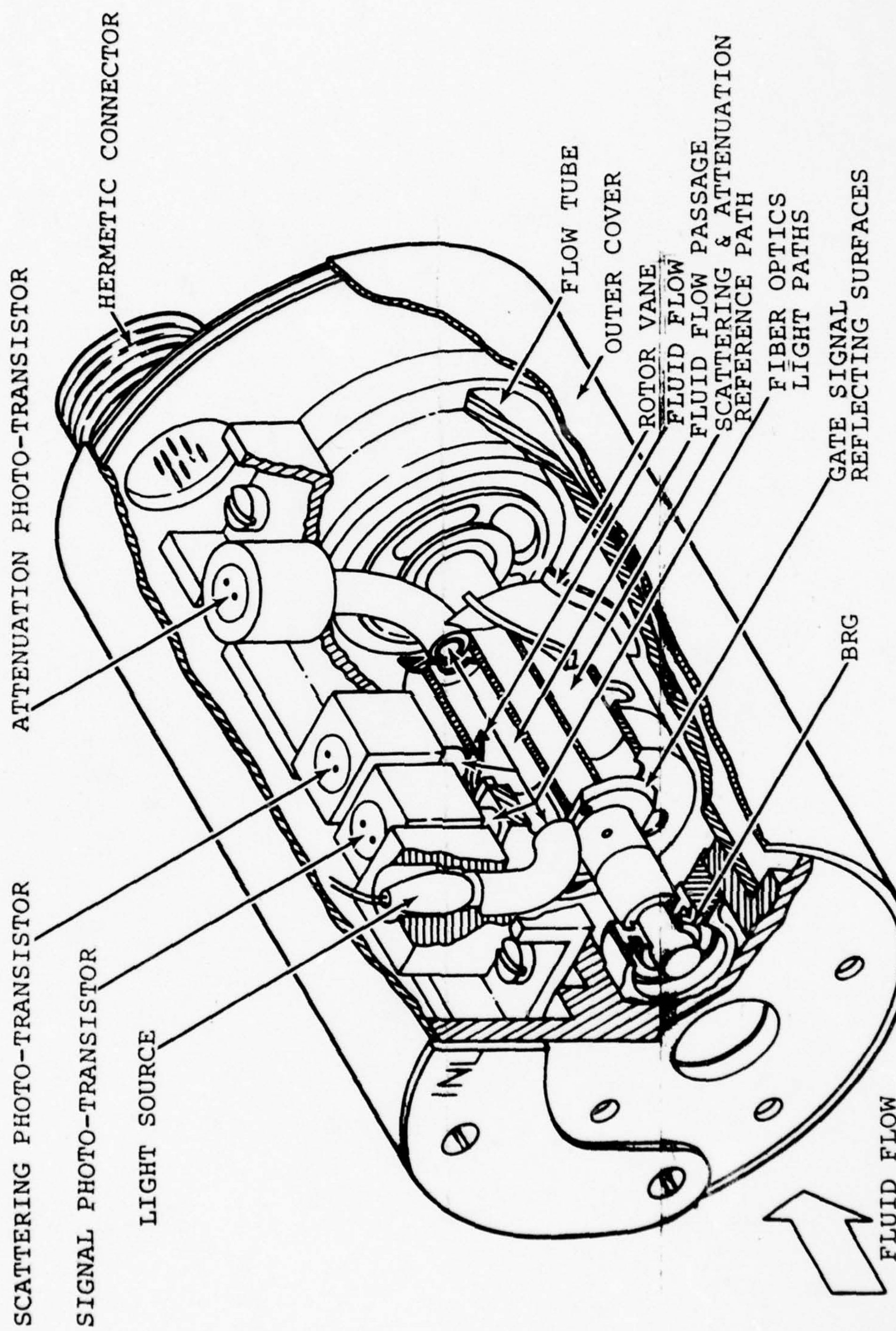

Figure 12. Environment One sensor unit.

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system is similar to ASOAP, i.e., manual or automatic trending is probably required to detect an abnormal rate of increase in the measured parameters. The major drawback to use of the system in a relatively inexpensive aircraft is cost. The 1973 cost of the equipment discussed here was approximately $4300.00.

4.3.2.4 Nucleonic Oil Debris Monitor

A nucleonic oil debris monitoring system was provided by USAAMRDL for evaluation. This equipment was designed and developed by Nucleonic Data Systems, Inc., Irvine, California, under contract to USAAMRDL. The system is shown schematically by Figure 13, and is described in detail by Reference (8). As oil flows through the sensor unit, it is exposed to a radiation source (plutonium 238). If metallic particles are present in the oil, X-rays are emitted in response to the incident radiation. These fluorescent X-ray emissions are sensed by a radiation detector, the output of which is electronically conditioned to provide a readout which is proportional to contamination level. A problem developed even before the unit was received, relative to the transportation, receipt, handling, and storage of radioactive material. Fortunately, BHT was already licensed in this regard by the State of Texas, and the license was amended to include the nucleonic monitor.

Installation into the test setup was difficult, both due to the fragile nature of the sensor, and the lack of suitable connecting fittings. During preliminary run-up of the test stand, the unit leaked profusely. It was also noted that the pressure drop across the entire oil monitor setup was unacceptably high. The oil monitors were removed and checked one at a time on a flow bench. At rated flow of 15 GPM, the Environment One Δ P was 4 psi, and the Franklin ΔP was 15 psi. Pressure drop across the nucleonic sensor was unrepeatable, at one point reaching 45 psi at 10 GPM. Per USAAVSCOM direction, the unit was returned to the vendor on 19 March 1974 and was not returned to BHT; therefore no further evaluation was possible.

4.3.2.5 Transmission Spectrometric Oil Analysis

AVSCOM requested that oil samples be obtained from the test transmission during the prognostic Degradation Rate Test and the Removal Limit Confidence Test conducted in the BHT test cell as discussed in Section 4.8. Two oil bottle samples were obtained as requested. One bottle was delivered to AVSCOM for analysis and the other bottle was delivered to the Vought Corporation Laboratory for analysis. The Vought Corporation Laboratory analysis is presented in Table VII.

4.3.3 Hydraulic Pump Monitoring

The measurement of hydraulic pump case drain flow was investigated

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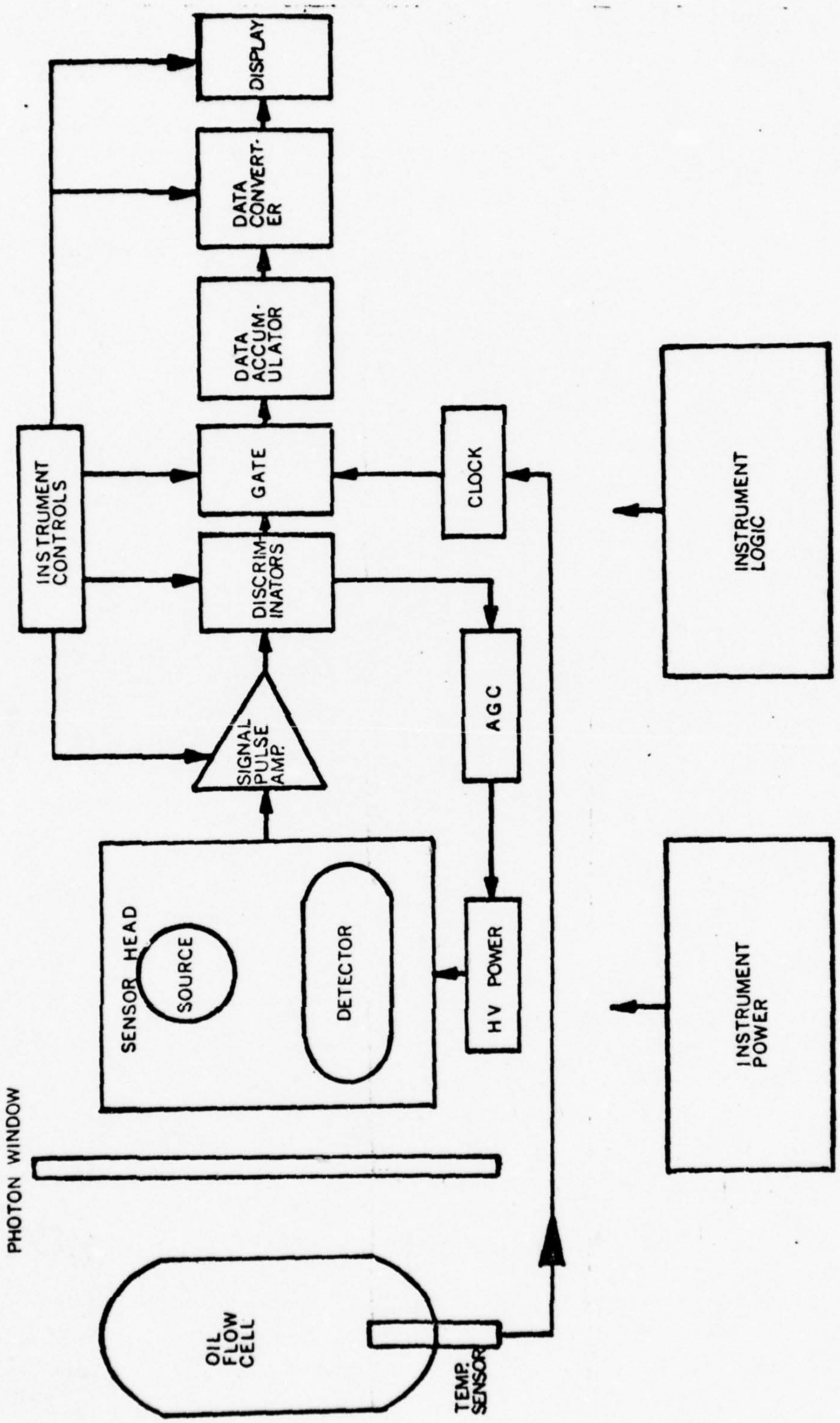

Figure 13. Nucleonic oil debris monitor schematic.

TABLE VII
TRANSMISSION SPECTROMETRIC OIL ANALYSIS
ATOMIC ABSORPTION

Fe - Iron
Cr - Chrome
Sn - Tin
Mg - Magnesium
Si - Silicon
Cu - Copper
Ag - Silver
Ni - Nickle
Al - Aluminum

(All data in parts per million)

Degradation Rate Test

Sample	Test Hours	Fe	Cr	Sn	Mg	Si	Cu	Ag	Ni	Al
				Test Block #1						
001A	5	1.2	0	3.0	0	0	.2	0	.3	2.0
002A	16	3.1	0	3.0	.36	0	1.3	0	.2	2.6
003A	30	3.9	0	3.0	.57	3.0	3.1	0	.1	1.8
004A	40	3.8	0	3.0	.58	3.0	3.1	0	.2	1.1
				Test Block #2						
005	6	3.5	0	3.0	.47	2.0	3.5	0	.3	1.7
006	20	3.0	0	4.0	.34	3.0	2.2	0	.1	.4
007	30	3.6	0	5.0	.41	0	2.3	0	.2	0
008	40	3.9	0	5.0	.42	1.0	2.2	0	.2	.3
				Test Block #3						
009	10	4.6	0	4.0	.47	0	2.1	0	.2	.6
010	20	4.7	0	5.0	.22	0	.4	0	.4	2.3
011	30	6.1	0	3.0	.50	0	.7	0	.4	.7
012	40	8.7	0	3.0	.61	0	1.0	0	.5	6.1

During these tests the only discrepant transmission implant was a spalled upper sun gear. Degradation of the gear during the tests was negligible, as indicated by the small increase in iron.

TABLE VII. (Cont'd)
Removal Limit Confidence Test

Sample	Test Hours	Fe	Cr	Sn	Mg	Si	Cu	Ag	Ni	Al
					Test Block #1					
013A	0	4.2	0	0	.73	1.0	0	0	0	.4
014A	10	5.8	.2	0	.85	0	1.0	0	0	.7
015A	20	12.0	.2	0	1.07	2.0	1.5	.1	.2	.3
016A	30	14.9	.4	0	1.23	1.0	2.1	.2	.2	.9
017A	40	15.7	.3	0	1.33	1.0	11.2	.6	.1	2.6
018A	50	18.1	.7	0	1.59	1.0	13.8	.9	.5	3.6
019A	60	18.8	.5	0	1.60	4.0	14.2	.8	.4	3.2
020A	70	22.9	.5	0	1.81	1.0	16.0	.8	.5	4.3
022A	90	24.8	.6	0	2.18	1.0	32.4	.6	.5	6.4
023A	91.8	25.5	.6	0	2.33	4.0	34.2	.6	.8	9.7
					Test Block #2					
024A	0	2.8	0	0	.38	6	.5	0	0	1.4
025A	20	10.4	0	0	.67	2	3.2	0	.3	4.4
026	30	10.2	0	0	.64	0	3.8	0	.3	3.2
027A	40	11.4	0	0	.69	5	4.2	0	.1	4.4
028A	50	13.0	0	0	.83	2	14.7	0	.1	5.7
029A	60	12.6	0	0	.83	0	23.8	0	.2	6.9
030A	70	13.8	0	0	.81	0	32.3	0	.2	10.9
031A	80	13.7	0	0	.89	3	32.8	0	.1	11.2
032A	90	10.8	0	0	.73	0	28.6	0	0	8.9
					Test Block #3					
033A	5	8.4	0	0	.56	0	2.0	0	.2	1.3
034A	10	10.1	0	0	.68	0	1.8	0	0	1.3
035A	20	14.7	0	0	1.04	0	2.6	0	.2	1.9
036A	30	17.2	0	0	1.31	0	2.8	0	.2	4.2
037A	40	18.2	0	0	1.65	0	2.8	0	.3	3.0
038A	50	19.8	0	0	1.85	4	2.9	0	.2	3.8
039A	60	18.5	0	0	1.97	0	2.7	0	.1	2.1
040A	70	020.2	0	0	2.10	0	2.6	0	.2	3.5
041A	80	022.8	0	0	2.51	0	3.0	0	.3	4.7
042A	90	021.8	0	0	2.73	1	2.8	0	.5	3.0
043A	100	021.3	0	0	2.73	1	2.5	0	.4	5.3

Numerous discrepant parts were installed during these tests, as indicated by increase in iron. During Block 1 & 2, a bronze planetary bearing retainer was destroyed, as indicated by the increase in copper. Based upon this limited sample, the SOAP results appear to correlate reasonably well with actual condition.

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as a possible method of diagnostic/prognostic pump health monitoring. An Arkwin flow monitor, as illustrated in Figure 14, was received from Arkwin Industries for evaluation in conjunction with UH-1H and AH-1G hydraulic pumps

The Arkwin unit was calibrated (Figure 15) and shipped to Fort Rucker, Alabama, and installed during ground run operations on three AIDAPS test helicopters. The impressed voltage (115 Vac) was monitored across Terminals 1 and 2 and the output voltage noted with the helicopter operating at 100% rotor RPM. The output voltage results from the three helicopters were 0.5, 0.2, and 0.1 Vac, which is below the specified measuring range of the flow monitor.

The Arkwin Flow Monitor was then installed on a test stand at CCAD, Corpus Christi, Texas, in the pump bypass flow measuring circuit. The pumps tested during this period were all within the allowable case flow range, and the Arkwin flow monitor read correctly to a low flow of 0.045 GPM. A review of pump test records was conducted for the first quarter of 1975 at the CCAD Quality Audit and Assessment Branch. Data from 160 AH-1G and UH-1H overhauled pumps showed an average case flow rate of 169 cc/min (0.045 GPM) with recorded maximum and minimum flow rates of 360 and 75 cc/min respectively. Two pump records noted high case drain flow as the reason for their initial rejection. One PVB-044-2 pump was rejected because of 0.7 GPM case flow and one PV3-044-8 pump was rejected because of 0.5 GPM case flow. Both pumps failed to meet minimum outlet flow requirements but the specific conditions were not noted.

Two operational AH-1G Vickers model PVB-044-2 hydraulic pumps and two rejected UH-1H Vickers model PV3-044-8 hydraulic pumps were tested in the BHT Mechanical Test Lab to determine how the bypass flow data compared with pump condition. The results are presented in Table VIII and Figure 16. The specification requirements for the AH-1G/UH-1H pumps obtained from WR 55-1650-159 are:

- Maximum case drain flow at zero pump output flow = 0.112 GPM (AH-1G); 0.122 GPM (UH-1H)

- Outlet pressure at zero pump output flow = 1500 to 1525 PSIG @5000 RPM (AH-1G); 1000 to 1025 PSIG @4170 RPM (UH-1H).

- Minimum output flow = 6.6 GPM @1350 PSIG & 5000 RPM (AH-1G); 5.18 GPM @900 PSIG & 4170 RPM (UH-1H).

The test results indicate that case drain flow is a positive candidate for diagnostic/prognostic pump health monitoring. The normal operating specification pump case drain flow was below the recording range of the particular flow monitor evaluated but otherwise the device operated satisfactorily when installed on the AIDAPS helicopters and pump flow test stands.

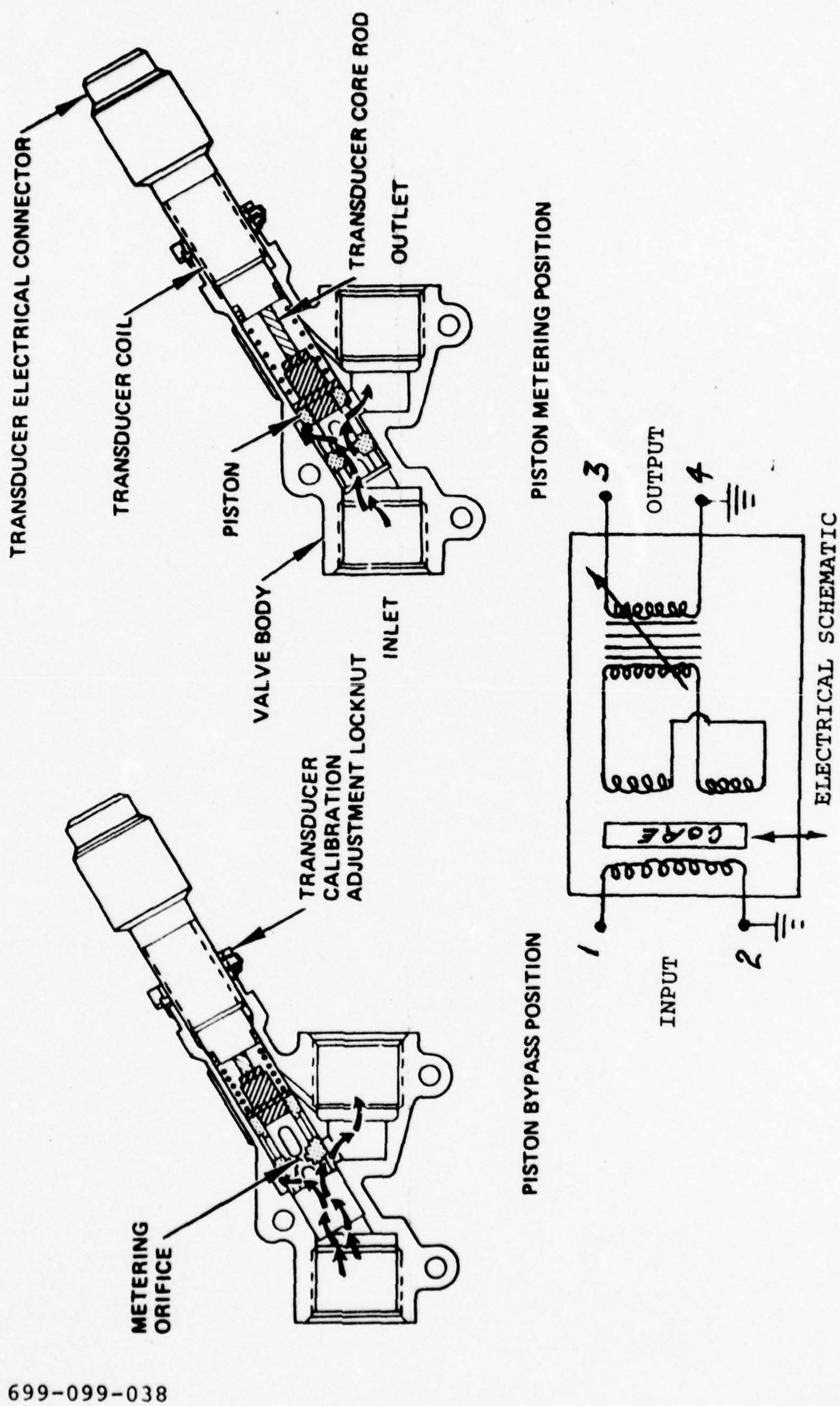

Figure 14. Arkwin flow monitor.

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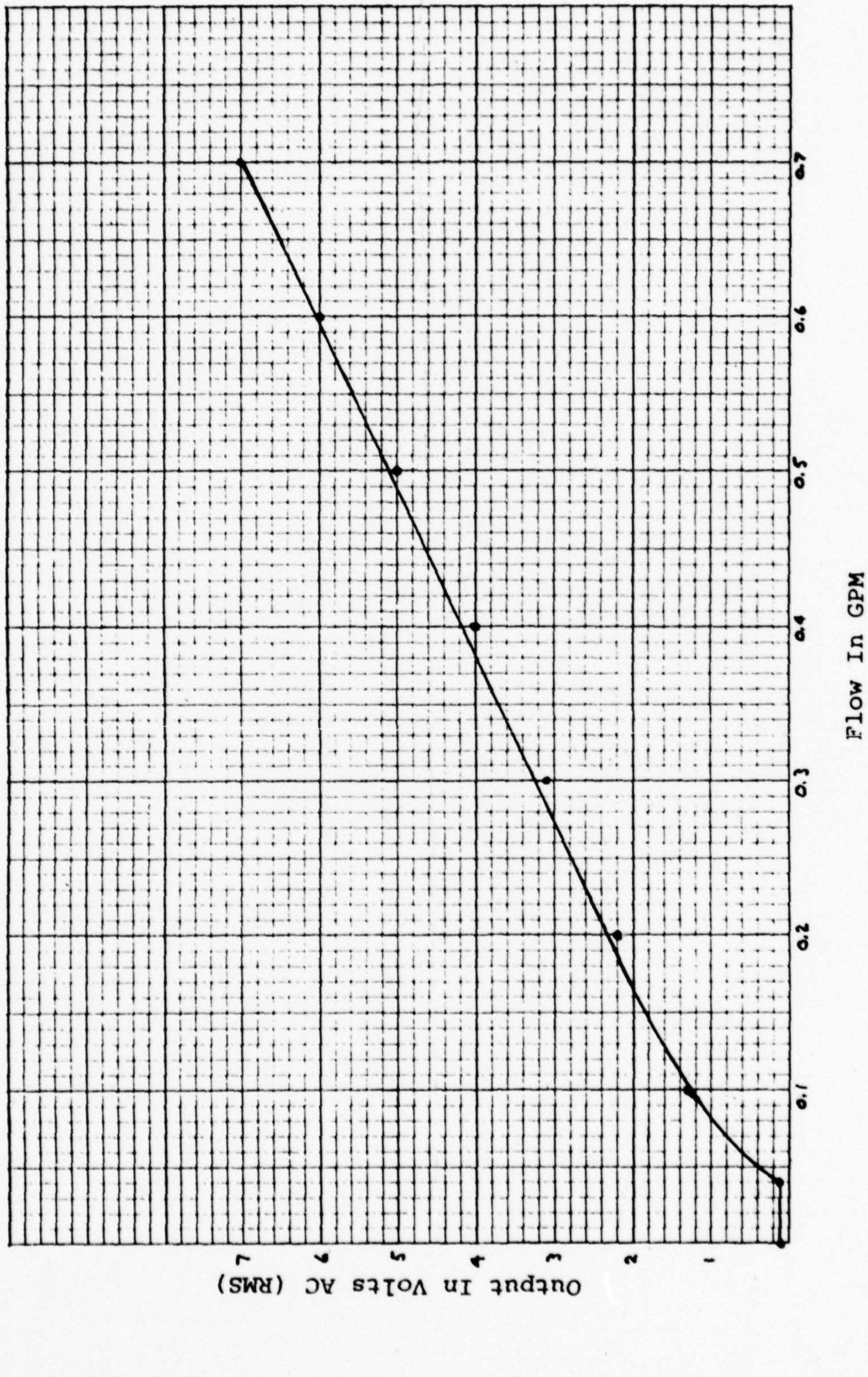

Figure 15. Arkwin flow monitor calibration.

TABLE VIII
AH-1G/UH-1H HYDRAULIC PUMP TEST

Helicopter Model	Pump		Outlet		Case Drain Flow (gpm)
	Model	Serial No.	Pressure (psi)	Flow gpm	
UH-1H	PV3-044-8	MX14396	800	0	4.5
			680	2	3.5
			520	3	2.8
			350	4	2.1
			120	5	1.0
			40	5.6	0.77
		XM-237297	400	0	4.1
AH-1G	PVB-044-2	HH23-3553	1500	0	1.06
			1350	6.6	1.22
		23-3625	1520	0	.405
			1350	7.0	.187

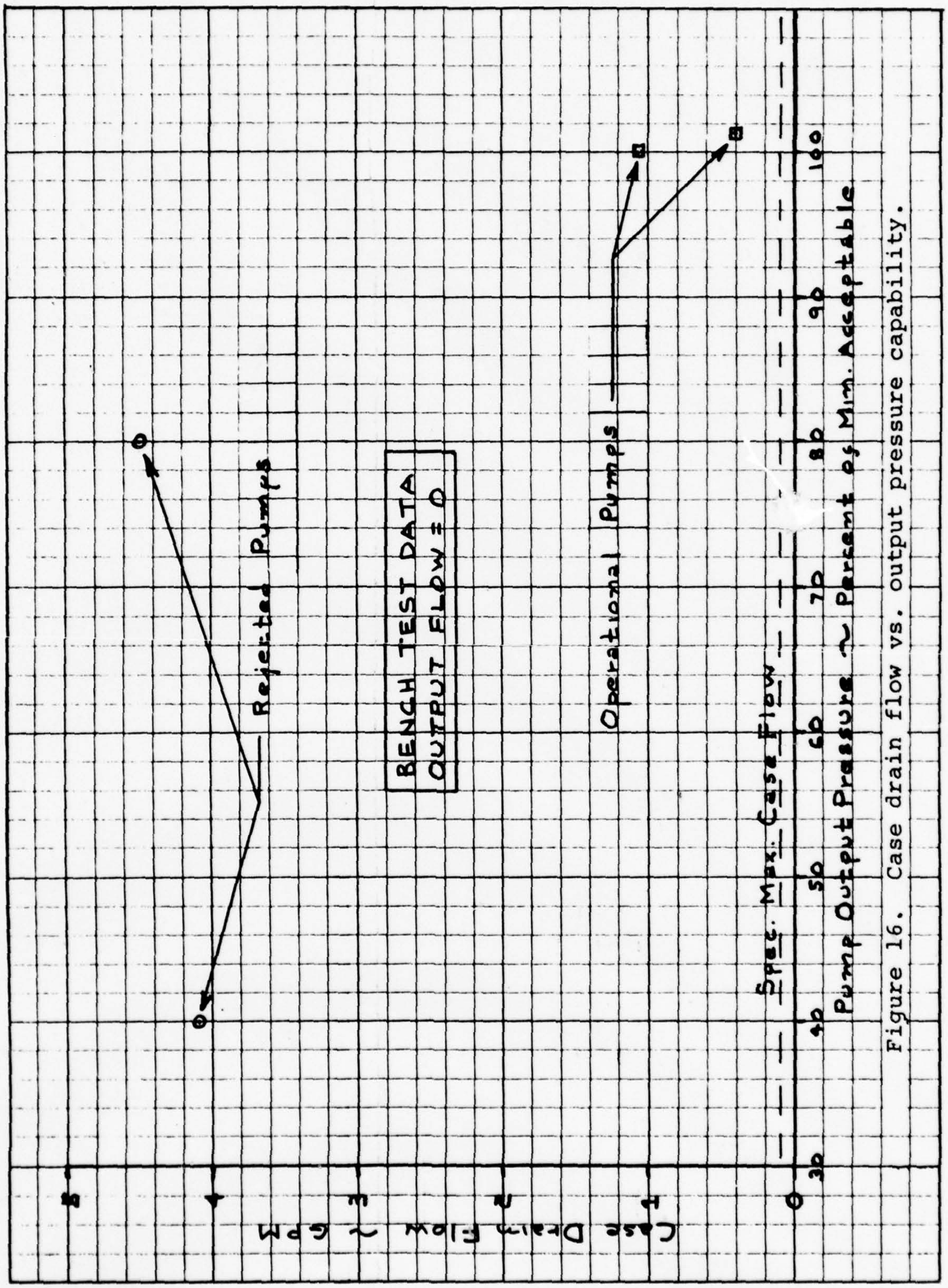

Figure 16. Case drain flow vs. output pressure capability.

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4.3.4 Upper Mast Bearing Debris Collector

An upper mast bearing debris collector was installed and tested during the AIDAPS Removal Limit Confidence Test. The debris collector is designed to trap debris from a degrading upper mast bearing, thus preventing secondary damage to other parts within the transmission. A chip detector is incorporated to provide early warning of a discrepant bearing. The 212-048-004-1 debris collector assembly is shown in Figures 17, 18, and 19 and consists of the following:

1 each, 212-048-004-3 Collector Weldment
1 each, 212-048-004-5 Top Case
1 each, 212-048-006-1 Chip Detector Adapter
5 each, 206-048-031-5 Stud
5 each, AN 320-4 Nut
5 each, AN 960-416L Washer
5 each, MS 24665-105 Cotter Key

Five of the ten production AN 126-366 studs used to secure the 204-040-349-9 mast plate to the top case were removed and replaced with the 206-048-031-5 studs. They were installed into the interior of the top case to allow the 212-048-004-3 collector weldment to be mounted. After installation to the required depth for collector attachment, adequate stud length did not remain for the mast plate mounting nuts. The tops of the nuts were even with the tops of the studs when installed. The condition was considered acceptable for test purposes.

The debris collector was installed for 91.8 hours of transmission operation. A spalled 204-040-136-9 mast bearing (Implant BHC-123) was installed in the transmission. The chip detector was activated six times by chips from the mast bearing. The chips trapped in the debris collector were not readily visible during the post run inspection due to the quantity of oil remaining in the collector. A magnet was utilized to remove any chips remaining in the collector (Figure 20). These chips had vibrated, or were washed to the outer radius of the collector, were evenly disbursed, and had not been flushed toward the chip detector. It is believed that in an operational helicopter the normal vibration and ship motion will move more of the debris toward the chip detector.

The 212-048-004-1 upper mast bearing debris collector served the purpose for which it was intended, trapping debris from a discrepant upper mast bearing and indicating the failure by means of the chip detector installation.

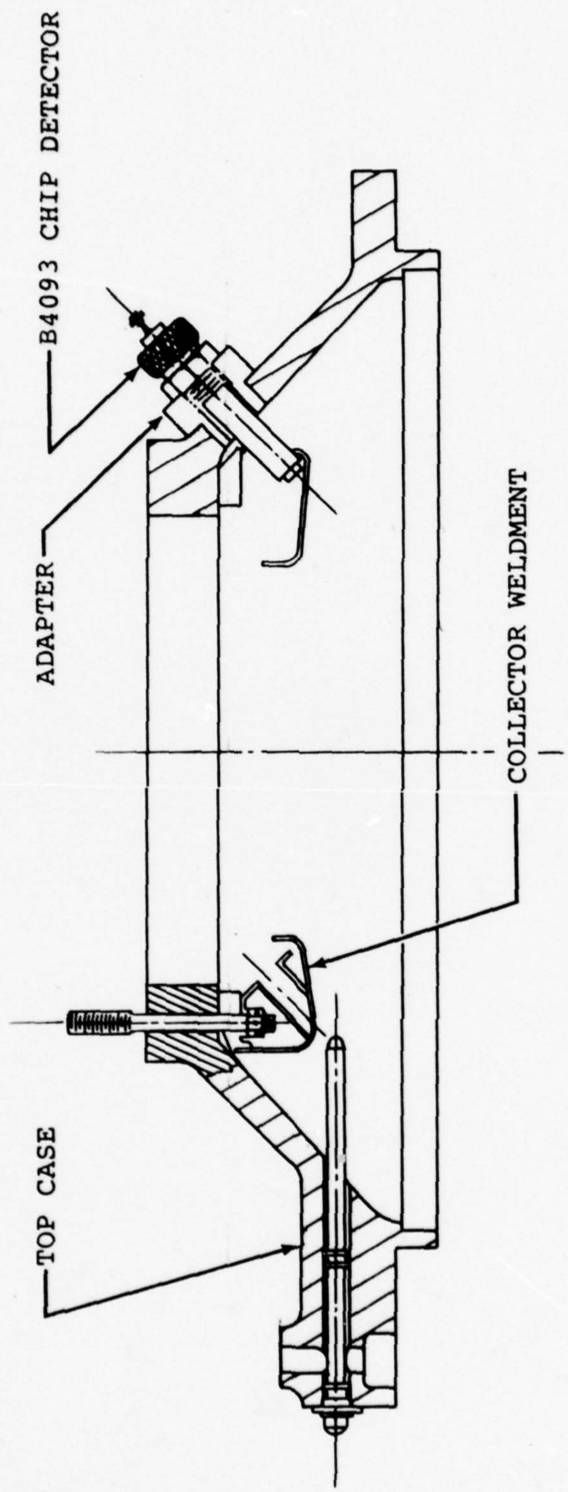

Figure 17. Upper mast bearing debris collector.

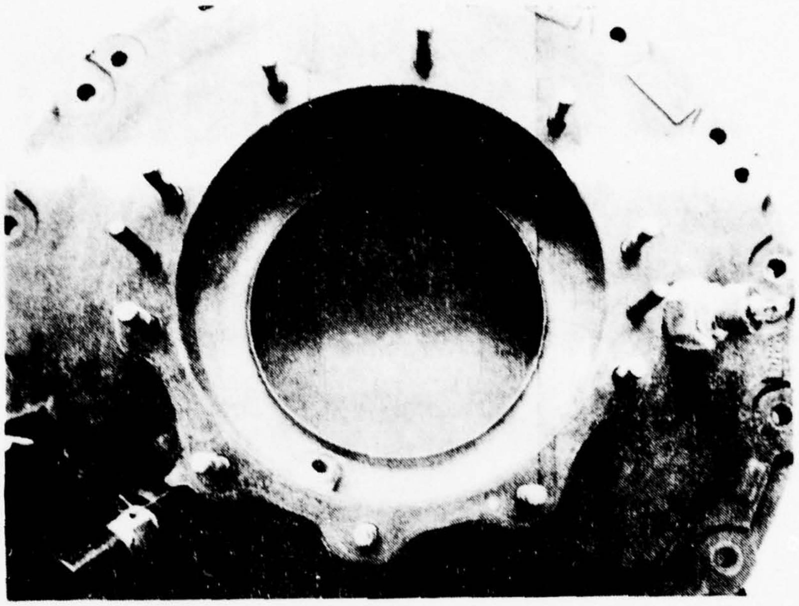

Figure 18. Collector weldment installed in top case.

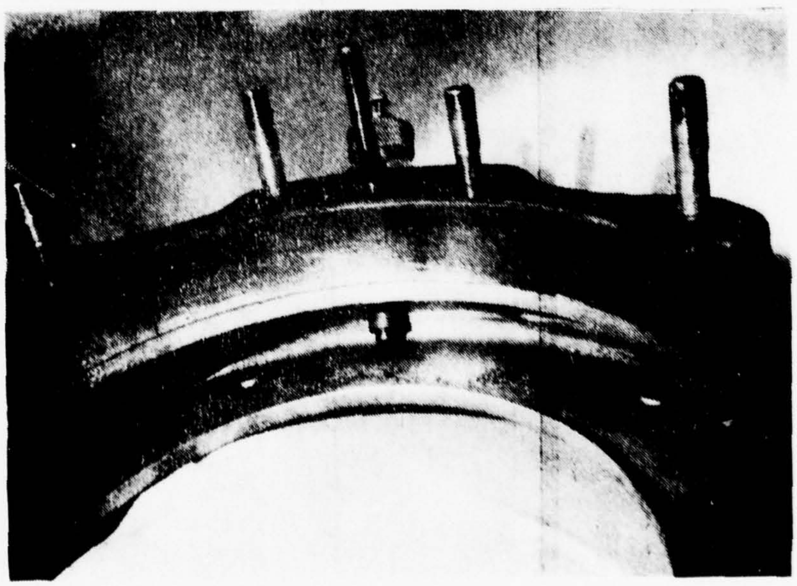

Figure 19. Installed position of the chip detector.

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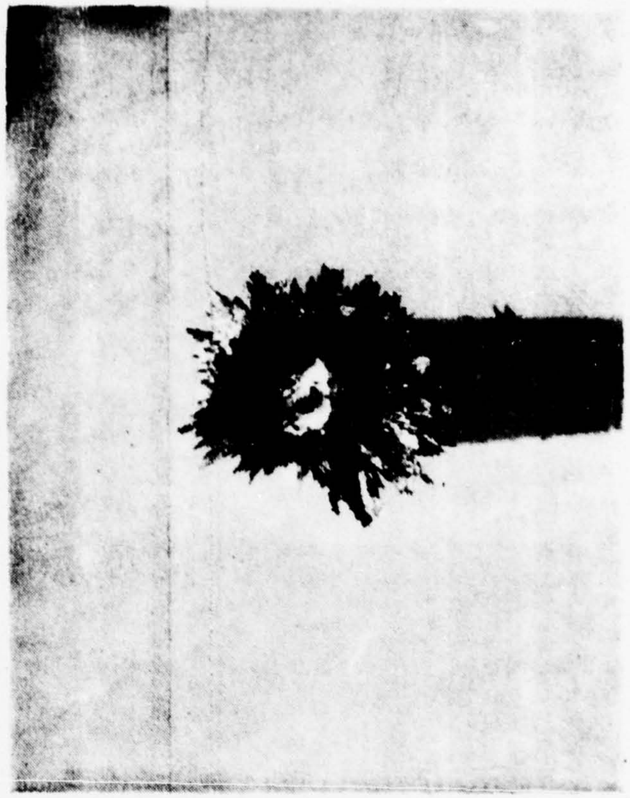

Figure 20. Mast bearing debris collected.

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4.3.5 Advanced Chip Detector Installations

The remotely indicating electric chip detector is a major airborne monitoring device installed in helicopter transmissions, gearboxes, drives, pumps and the oil wetted components of engines. The chip detector is used as a switch to activate a cockpit chip light and indicates the arrival of a conductive metal particle. This is, however, the only bit of information concerning the condition of the mechanical system that is transmitted. The low information content does not allow any trend analysis and current requirements demand that the pilot execute a precautionary landing. Despite this limited capability, the electric chip detector has been successful in reducing in-flight failures and secondary damage by indicating the generation of wear particles leading to the development of gear and bearing failure modes.

A recent Army evaluation of 290 precautionary landings resulting from the actuation of chip lights revealed the following: Approximately 51% of the chip indications were caused by normal wear fuzz; 25% were due to faulty electrical wiring and plug failures; 12% were of undetermined cause and only 12% were caused by actual failures. The electrical wiring faults should be easily corrected with state-of-the-art connectors. A desirable condition monitoring system should consist of a real time wear particle sensing device that is capable of distinguishing failure characteristic particles from normal wear fuzz. The Tedeco Fuzz-Discriminating Wear Debris Detection System and two BHT Fuzz Burn-Off Advanced Chip Detector Systems with these characteristics were evaluated during the Removal Limit Confidence Test in the BHT Transmission Test Cell as outlined in Appendix A.

4.4 Data Analysis - Task IV

Limited data analysis was required to insure that usable tape data was being generated in order to recommend instrumentation changes as required. A Federal Scientific UA-500 Spectrum Analyzer, as shown in Figure 3, was used to review each accelerometer signal and to try and detect signature changes between baseline and implant conditions. No significant change in the spectrum information was detectable between baseline and implant conditions; any vibration signal changes were lost in the overall noise level. It became obvious that more signal conditioning was required to assure that the vibration instrumentation would be able to detect the implanted fault. As a result, a High Frequency Resonance (signal conditioning) technique was investigated.

4.4.1 Mechanical Technology High Frequency Resonance Technique

Mechanical Technology Incorporated proposed to apply their vibration analysis technique to the analysis of vibration data on the BHT generated AIDAPS data tapes. The MTI technique is

outlined in Reference (9). A subcontract was awarded to MTI in November 1974 and data was provided to MTI for analysis covering 30 tests of UH-1H 42-degree gearboxes. Included were no-defect baseline tests, and tests in which a defective gear or bearing was implanted.

The principle of the High Frequency Resonance Technique is that defective parts will ring at their resonance frequencies and the signal of the defect which causes the ringing appears as a modulation of the resonant frequency. Two reasons were offered by MTI for using this technique. First, the resonant frequencies are usually much higher than other frequencies present in the vibration spectrum. A narrow band-pass filter can therefore be used to pass only the portion of the vibration spectrum near the resonant frequency, thus rejecting all low frequency noise. Second, it is not necessary to store a no-defect baseline signature for comparison with a defect signature because the resonant frequency is not excited and no signal is present unless a defect exists.

The task assigned to MTI was to identify the implant, if installed, from the data only, without knowing the test conditions. MTI was provided the following information with the data tapes:

- The BHT Test Plan outlining the instrumentation, recording equipment, and test procedures.
- Detail drawings of the 42-degree gearbox, bearings, and gears.
- Test stand data logs with the implant identification data removed.
- A listing of the gear mesh, bearing and shaft frequencies of interest within the 42-degree gearbox.

The data signals used for this analysis were from a single Endevco 6222M26 accelerometer mounted on the external housing of the 42-degree gearbox, near the input quill shaft, as shown in Figure 9. Some of the data tapes shipped from Airesearch to MTI contained implant information, but this did not appear to influence the results. All the MTI results were substantiated by analysis and in one case did not agree with the implant information. Table IX summarizes the results of the analysis that is presented in Reference (10).

Positive detection and identification of bearing defects was accomplished when the vibration sensor was located near the defect. In the three cases of implants not detected, the implant was installed in the output quill and the transducer monitored was on the input quill. The Endevco transducer installed for this test was not an optimum design for use with this analysis

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TABLE IX. SUMMARY OF MTI DEFECT DETECTION RESULTS

Case No.	IMPLANT Ident.	IMPLANT Nomenclature	IMPLANT Location (42° G/B)	Defect Description	MTI Analysis	Score
1	BHC-001	Ball Bearing	Input Quill	O/R Spall	Ball Bearing O/R Defect	100
2	BHC-002	Ball Bearing	Input Quill	O/R Spall	Ball Bearing O/R Defect	100
3	BHC-003	Ball Bearing	Input Quill	O/R Spall	Ball Bearing O/R Defect	100
4	---	--Baseline	S/N 2245--		Very Slight Ball Bearing O/R Defect	75
5	---	--Baseline	S/N 1182--		No Defect	100
6	BHC-003	Ball Bearing	Output Quill	O/R Spall	No Defect	Note 1
7	BHC-004	Bevel Gear	Input Quill	Scored	Gear Defect	100
8	BHC-005	Roller Brg	Input Quill	Flat Roller	Roller Bearing Roller Defect	100
9	BHC-006	Roller Brg	Output Quill	Flat Roller	Roller Bearing Roller Defect	100
10	BHC-006	Roller Brg	Input Quill	Flat Roller	Roller Bearing Roller Defect	100
11	---	--Baseline G/B	S/N 887--		No Defect	100
12	BHC-007	Ball Bearing	Input Quill	O/R Spall	Ball Bearing O/R Defect	100

TABLE IX. (Cont'd)

Case No.	IMPLANT Ident.	Nomenclature	Location (42° G/B)	Defect Description	MTI Analysis	Score
13	---	--Baseline	S/N 887--		No Defect	100
14	---	--Baseline	S/N 2245--		No Defect	100
15	---	--Baseline	S/N 1182--		Very Slight Ball Brg O/R Defect	75
16	BHC-007	Ball Bearing	Output Quill	O/R Spall	Ball Brg O/R Defect	100
17	BHC-007	Ball Bearing	Input Quill	O/R Spall	Ball Brg O/R Defect	100
18	BHC-007	Ball Bearing	Output Quill	O/R Spall	No Defect	Note 1
19	BHC-007	Ball Bearing	Input Quill	O/R Spall	Ball Brg O/R Defect	100
20	BHC-007	Ball Bearing	Output Quill	O/R Spall	Very Slight Ball Brg O/R Defect	Note 1
21	BHC-009	Ball Bearing	Input Quill	O/R Spall	Ball Bearing O/R Defect	100
22	BHC-010	Ball Bearing	Input Quill	O/R Spall	Ball Bearing O/R Defect	100
23	BHC-011	Ball Bearing	Input Quill	O/R Spall	No Defect	0
24	BHC-012	Roller Brg	Input Quill	*I/R Spall	Rlr Brg I/R Defect	100
25	BHC-013	Roller Brg	Input Quill	I/R Spall	Rlr Brg I/R Defect	100

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TABLE IX. (Cont'd)

Case No.	IMPLANT Ident.	IMPLANT Nomenclature	IMPLANT Location (42^{O} G/B)	Defect Description	MTI Analysis	Score
26	BHC-014	Roller Brg	Input Quill	I/R Spall	Roller Brg I/R Defect	100
27	BHC-015	Bevel Gear	Input Quill	Scored	Gear Defect & Very Slight Ball Brg Defect	50
28	BHC-016 017	Gearset	-----	Scored	Gear Defect	100
29	BHC-018	Ball Brg	Input Quill	Ball Spall	Ball Brg Ball Defect	100
30	BHC-019	Ball Brg	Input Quill	I/R Spall	Ball Brg I/R Defect	100

Note 1: Defect implanted in output quill was not detected by accelerometer on input quill. The same defect was correctly identified when inplanted in the input quill.

O/R = Outer Race

I/R = Inner Race

technique. As stated in Section 4.2 the Endevco accelerometer was chosen for this location by the Airesearch Manufacturing Company to be compatible with their analysis technique.

The gear implants were detected but more effort was indicated to finalize a technique. MTI recommended a frequency modulation technique to identify gear defects. In this procedure the vibration sensor signal was FM modulated around the 42-degree gearbox gear mesh fundamental frequency. A one-per-revolution variation is present in almost any gearset and an increase in the variation should indicate a defective gear set. The frequency detection results are presented in detail in Reference (11). There did not appear to be any correlation between the results of the analysis and the presence of a gear defect in the 42-degree gearbox.

4.4.2 BHT Bearing Defect Vibration Monitoring

Because of the promising results obtained from the MTI bearing analysis program, bearing defect detection and monitoring equipment was designed and fabricated at BHT for evaluation in conjunction with the AIDAPS transmission laboratory tests. The equipment utilizes high frequency vibration resonance fault detection and peak/average fault monitoring. The results reported are for the second block of testing during the Removal Limit Confidence Tests and are presented in Appendix B. Twenty known implanted bearing defects were detected. Ten Category "B" bearing defects not documented during the test build-up were also detected and verified by teardown inspection. Three defects were indicated that were not verified by the teardown inspection; however, in each of these cases the bearings contained other defects which were identified. The automatic monitor activated a warning when a defect was present.

4.4.3 BHT Gear Defect Vibration Monitoring

Gear defect detection circuitry was designed and fabricated by BHT for evaluation in conjunction with the AIDAPS transmission laboratory tests. The circuitry utilizes FM demodulation of the gear mesh fundamental frequency and its sidebands to establish a defective gear, similar to the MTI analysis technique. The increase in sideband energy when a gear fault was present was confirmed and fault monitoring was provided by comparing the ratio of the RMS to peak value of the demodulated signal. The results are reported in Appendix B.

4.5 Fault Isolation Logic - Task V

The UH-1H and AH-1G functional systems were analyzed to define the parameters required to be monitored and integrated into logic flow diagrams for each subsystem in order to: detect the most probable failure modes; isolate the failure directly to a line

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replaceable unit (LRU); or provide maintenance and/or inspection requirements that permit isolation of an indicated subsystem failure to an LRU with a minimum amount of additional trouble-shooting. The subsystem analysis and logic diagrams are presented in Appendix C (except for engine gas path logic or mechanical vibration analysis logic). The intent of the logic presented is to provide information to preclude incipient gas path and vibration problems. The information also adds confidence and back-up information to the gas path and vibration logic. The information provided covers only one system where redundant or identical systems occur, such as the AH-1G hydraulic and stability augmentation systems (SAS). The logic is identical for either hydraulic system or any of the SAS. The UH-1H and AH-1G logic is separated for clarity, even though many systems are similar.

The UH-1H fault logic diagrams were published in Reference (12) during the AIDAPS contractor's UH-1H flight test data collection effort at Ft. Rucker, Alabama, for incorporation into the final logic developed for the AIDAPS prototype hardware. Some of the test points required to monitor the mechanical systems on the UH-1H were installed during the AIDAPS flight test data collection phase and these locations are noted in the tables of Appendix C. The AH-1G effort was delayed and finally cancelled by AVSCOM. Presentation of the AH-1G logic was therefore delayed until final report publication.

4.6 Installation/Interface Data - Task VI

AIDAPS installation and interface data was provided for use by the AIDAPS equipment contractor in designing and installing the AIDAPS equipment in UH-1H Helicopters. Installation data was provided for installation of the AIDAPS flight data collection equipment and prototype AIDAPS hardware. BHT also provided an evaluation to AVSCOM of the AIDAPS contractor's flight data collection and prototype hardware installations by reviewing the installation drawings and hardware installed. The following is a summary of that review.

4.6.1 Flight Data Collection Installation/Interface and Review

The following drawings were provided to Airesearch for information in installing the flight data collection system:

205-470-001	Three View Drawing
205-900-001	General Arrangement, Helicopter Assembly
205-470-002	Inboard Profile
204-040-003	Gearbox Assembly, 42° Tail Rotor Drive
204-040-012	Gearbox Assembly, 90° Tail Rotor Drive
204-040-016	Transmission Assembly, Universal
204-040-366	Mast Assembly, Transmission
209-040-366	Mast Assembly, Transmission
204-040-400	Pinion, 90° Gearbox, Tail Rotor Drive
Sketch	Recommended vibration transducer locations

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A review of the Airesearch Manufacturing Company gas path data collection equipment was conducted by BHT personnel at Ft. Rucker, and reported to AVSCOM in BHT Letter 80:JVH:rcn-1643, dated 31 January 1974. The review noted that sensor installation and circuit schematic drawings had not been provided. Switching procedures to obtain transient loading of the main generator, ICS terminal location information to obtain voice recording of the pilot's comments on the data tapes, and interface problems with the aircraft Exhaust Gas Temperature instrumentation were informally discussed with BHT, AVCO Lycoming and Airesearch personnel. Solutions were suggested and incorporated into the AIDAPS data collection hardware installation. Weight and balance of the gas path data collection system installed in the UH-1H test helicopters "Bearcat" #11 and #12 were calculated and are presented in Table X.

Vibration data collection system drawings were received from Airesearch and reviewed at BHT. Discrepancies regarding the location of transmission, hanger bearing, and gearbox sensors were noted and informally discussed with Airesearch personnel. During a trip to Ft. Rucker (7-18 January 1974), the discrepancies were reviewed with Airesearch and USAADTA personnel.

The review of the installation was reported to AVSCOM in BHT Letter 80:JVH:rcn-1646, dated February 1974. Weight and balance information for the vibration data collection systems installed in the UH-1H test helicopters "Bearcat" #13 and #14 was provided to AVSCOM and is presented in Table XI.

A final review of the Airesearch gas path and vibration data collection system for the UH-1H was completed and reported to AVSCOM in BHT Letter 80:JVH:dw-257, dated 14 March 1974. The discrepancies noted in the previous reviews were corrected and weight and balance data for the incorporation of the vibration data collection system with the gas path data collection system installed in the UH-1H test helicopters "Bearcat" #11 and #12 was provided to AVSCOM and is presented in Table XII.

AH-1G engine installation performance effects data was provided to Airesearch via BHT Letter 80:JAM:dhw-291, 21 May 1974. The engine installation losses for the AH-1G are as follows:

- Engine inlet pressure recovery and temperature rise as shown by Figure 21.

- Airbleed to the oil cooler fan is approximately 0.6 percent of engine airflow. For simplicity, this value may also be used for the UH-1H if desired, in lieu of the curves previously provided.

- Airbleed to the Airesearch Environmental Control Unit is approximately 15.3 lb/min. This value is maintained fairly

TABLE X
WEIGHT AND BALANCE
AIRESEARCH GAS PATH DATA COLLECTION SYSTEM INSTALLATION

Name	P/N	Wt (lb)	C.G.	Moment
SPC	TE800110-1	23.00	173.25	3984.75
Inverter	S120-115A-400	7.25	184.50	1335.63
FDAU	949684	16.25	191.50	3091.88
Recorder	948010-2	19.50	195.00	3632.50
Data Entry Panel	TE800110-2	2.80	46.00	128.00
Pallet - Racks Wire	1284262	37.00	186.00	6882.00
		105.80	180.10	19054.76

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TABLE XI
WEIGHT AND BALANCE
AIRESEARCH VIBRATION DATA COLLECTION SYSTEM INSTALLATION

Bearcat #13 and #14

Name	Part Number	Wt. (lb)	C.G. (in)	Moment (in-lb)
SPC	TE-800110-3	24.00	173.25	4158.00
AR	MARS-2000	40.00	195.00	7800.00
Pallet-Racks & Wire	---	19.50	186.00	3627.00
Wiring	---	20.50	186.00	3813.00
Control Panel	---	1.10	51.45	56.60
*Bracket	299-096-100	0.61	149.96	91.48
	299-096-101	0.64	149.96	95.97
	299-096-102	0.51	143.61	73.24
	299-096-103	0.86	128.99	110.93
	299-096-104	0.18	139.31	25.08
	299-096-105-1	0.32	431.36	138.04
	299-096-105-9	0.51	422.58	215.52
	299-096-106	0.76	477.73	363.08
	TE-26753-02	0.25	210.45	52.61
	TE-26754-01	0.39	196.75	76.73
	TE-26755-01	0.69	182.63	126.02
	TE-26758-01	0.35	180.96	63.34
	1284286-1	0.58	174.46	101.19
SUBTOTAL		111.75		20987.83
	1284285-1	0.60	○ 219.06	131.44
TOTAL		112.35	187.98	21119.27
		0.60	△ 292.66	175.60
TOTAL		112.35	188.37	21163.43
		0.60	□ 358.83	215.30
TOTAL		112.35	188.72	21203.13

*Weight includes sensor installed on the bracket.

○ Fwd Position
△ Mid Position
□ Aft Position

TABLE XII
WEIGHT AND BALANCE
VIBRATION DATA COLLECTION SYSTEM
INSTALLED WITH THE GAS PATH DATA COLLECTION SYSTEM

No change in weight or arm distance for the gas path analysis data collection system or vibration analysis data collection system when installed together. The total weight and C.G. of the system is as follows:

Name	Wt (lb)	C.G.	Moment
Gas Path Data Collection System	105.80	180.10	19054.76
Vibration Data Collection System	112.35	188.72	21203.13
TOTAL	218.15	134.54	40257.89

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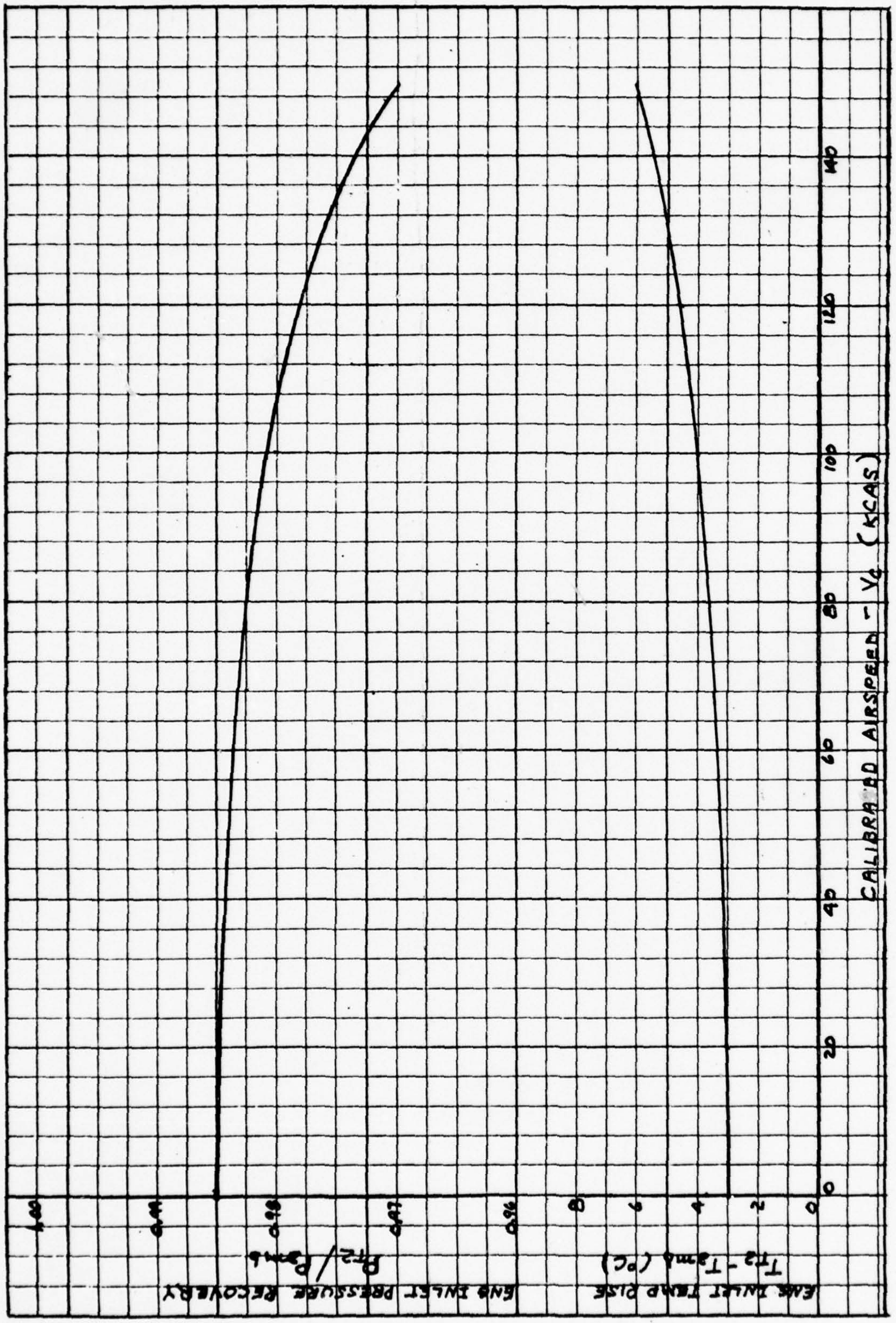

Figure 21. AH-1G engine inlet performance (particle separator installed)

constant by means of a pressure regulator.

- The AH-1G does not use air driven fuel pumps.

- The AH-1G generator is engine driven, resulting in an average N_1 power extraction of 5 HP.

BHT was requested by Airesearch to define a modification of the 299-066-106 accelerometer mounting bracket on the 90-degree gearbox to accommodate an Endevco 6222 M26 pickup in lieu of the Columbia 1111-1. In response, the following modifications were reported to AVSCOM and Airesearch via BHT Letter 80:RBP:dhw-323, dated 13 August 1974.

- Remove the existing 1.20 inch x 1.06 inch x 0.22 inch canted base plate, P/N 299-096-106-7, from the P/N 299-096-106-1 90-degree gearbox bracket assembly.

- Fabricate a P/N 299-096-105-15 base plate used on the P/N 299-096-105-9 42-degree gearbox bracket assembly (for Endevco P/N 6222M26 accelerometer).

- Weld the Item 2 base plate in the location of the removed Item 1 base plate.

BHT was advised by Airesearch that the P_1, CDP, and Torque Pressure Transducers for the data collection flight test aircraft at Fort Rucker were being moved to a lower temperature environment. The installation data was reviewed for possible installation effects on engine operation, airframe structure and interference with other installed airframe components. The review results transmitted to AVSCOM per BHT Letter 80:JVH:dhw-340, dated 17 September 1974 are summarized as follows:

- Lycoming personnel indicated that the engine system operation should not be affected by the additional sensors and lines. The maximum compressor discharge air temperature is 560°F. The high temperature hose is tested per specification at 450°F $\pm$ 10°F, however, this hose is presently used in this type application and should be acceptable.

- BHT personnel indicated that the attaching airframe structure is adequate to support the brackets and sensors. The 205-030-279 floor access cover must be removed to provide for line routing. The removal is considered acceptable, but is not indicated on the Airesearch Drawing 1284291.

- The relocation of the P_1, CDP, and Torque Pressure transducers as outlined in the data received was considered acceptable for the data collection flight test aircraft at Fort Rucker, Alabama. The installation was not considered optimum as a permament installation for the AIDAPS prototype design.

Per Airesearch request an evaluation was made of the feasibility of installing a fuel mass flowmeter in series with a turbine flowmeter and an MS 28034 type temperature probe. The evaluation indicated the proposed installation was satisfactory providing the installation pressure drop remained negligible, and straight line runs on either side of the flowmeters were maintained. It was recommended that a Lycoming flight test fuel flowmeter installation used on a UH-1H test helicopter located at Avco Lycoming be considered as an alternative. The review was completed and the results reported to AVSCOM in BHT Letter 80:JVH:peb-44, dated 22 January 1975.

4.6.2 AIDAPS Prototype Installation/Interface and Review.

Airesearch Aviation personnel visited BHT on 9 and 10 May 1974 to finalize installation data requirements. After viewing UH-1H and AH-1G aircraft, and consulting with BHT designers, the Airesearch representatives requested the following drawings, which were delivered via BHT Letter IM-IOW-kw-1038, 31 May 1974.

212-030-263	ARC-102 Mounting
205-475-025	Wiring Diagram
205-075-036	Wiring Installation
209-470-002	Inboard Profile
209-075-006	Electrical Installation
209-075-115	Electrical Installation
209-075-008	Electrical Installation
209-075-003	Electrical Installation
209-060-903	Aft Firewall
209-030-125	Upper Fuel Cell Panel
209-030-106	Canted Bulkhead Panel
209-030-396	Tail Boom Shelves
209-030-893	Tail Boom Shelves
209-961-171	Tail Boom Shelves
209-030-827	Tail Boom Disconnect
209-075-220	D.C. Circuit Panel

Helicopter vibration and temperature environmental data, and vibration test recommendations for AIDAPS equipment, were submitted via BHT Letter 80:JVH:peb-41, 10 January 1975. The results are presented in Appendix D.

A review of Airesearch Drawing PA-116378, Bleed Air System Interface Wiring, was completed and approved via BHT Letter 81:RBP: peb-55, 6 February 1975. The installation posed no problem to the UH-1H Bleed Air System, provided the 150 kilohm isolation impedence was maintained.

The installation data package for the prototype AIDAPS equipment was received. The "Supplementary Engineering Data" was not complete as follows:

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a. No stress calculations were included.
b. The electrical load analysis was incomplete.

The review of the installation data package for the prototype AIDAPS equipment was informally discussed with Airesearch personnel. Formal results of the data review were delayed pending receipt of the revised electrical load analysis and stress analysis reports. Upon receipt of the requested information, the review of the installation data was completed. Results of the review and weight and balance information as presented in Table XIII were provided to Airesearch in BHT Letter 81:JVH: peb-160, dated August 1975. As a result of the review a partial set of drawings incorporating changes to the AIDAPS prototype installation was received from Airesearch under cover of Letter CADJB:5633:0926, dated 26 September 1975. The revised drawings were satisfactory.

The Airesearch Phase V Coordinated Test Plan (Draft) 75-11738, dated 20 August 1975, was received during the AIDAPS Coordination meeting at Airesearch, 21 August 1975. The draft described the plan of accomplishment for the Airesearch bench and airborne tests of the prototype AIDAPS system prior to and during the development tests scheduled for Ft. Rucker. The test plan was reviewed and comments concerning the plan were submitted to AVSCOM in BHT Letter 81:JVH:peb-190, dated 11 September 1975, and are summarized as follows:

- The vibration and temperature testing does not consider the recommendations outlined in BHT Letter 80:JVH:peb-41, dated 10 January 1975 that were solicited by Airesearch and presented in Appendix D.

- BHT does not agree with the Airesearch philosophy that a diagnostic system which detects minor degradations would not be effective and is undesirable. An AIDAPS System that has the ability to detect minor degradations will be desirable upon implementation into an operational helicopter model. The diagnostic removal limits can be set low and continuously updated (as confidence is assured that the limits can safely be increased) to the highest practical limit. The prognostic logic can be developed by tracking the increase and interval of the diagnostic indications. Tracking an operational fleet of aircraft will result in a large statistical sample and a high confidence level in the data.

- Valid implants should be any implants that meet the category degradation for fault detection. It was recommended that new covert implants with upper limit "C" and "D" category degradation be introduced in the program.

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TABLE XIII
WEIGHT AND BALANCE
AIDAPS PROTOTYPE INSTALLATION
UH-1H

Installation Drawing 1284296	Part Number	Wt (lb)	C.G. (in)	Moment (in-lb)
View A-A	1284298 Bracket 6222M26 Sensor	0.34 0.20	143.61	77.5494
View A-A	1284299 Bracket 6222M26 Sensor	0.18 0.20	128.99	49.0162
View C-C	1284297 Bracket 6222M26 Sensor	0.40 0.20	149.96	89.9760
View E-E	1284300 Bracket 6222M26 Sensor	0.17 0.20	139.31	51.5447
View G-G	PA116374 Bracket 6222M26 Sensor	0.26 0.20	422.58	194.3868
View K-K	1284308 Bracket Installation 3255-9101 Sensor 3255-9201 Sensor 3135-7708 Sensor	1.82 0.45 0.45 0.45	211.06	669.0602
View L-L	1284286 Bracket 6222M26 Sensor	0.38 0.20	174.76	101.3608
View L-L	PA116375 Bracket 6222M26 Sensor	0.15	183.82	64.337
View L-L	TE-26754 Bracket 6223 Sensor	0.25 0.19	196.75	86.57

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TABLE XIII. (Continued)

Installation Drawing 1284296	Part Number	Wt (lb)	C.G. (in)	Moment (in-lb)
View L-L	1284314 Oil Monitor	0.88	194.30	306.9940
	MS 28034-3 Sensor	0.50		
	PLC-50-A2 Sensor	0.20		
View L-L	1284310 Bracket	1.35	190.71	295.6005
	805193 Syncro	0.20		
View L-L	56 BP17B Sensor	0.50	179.42	89.7100
	HAC 15753 Sensor	0.15	202.28	30.3420
View M-M	1284296 Bracket	0.16	210.45	73.6575
	6233 Sensor	0.19		
View M-M	TE-26755 Bracket	0.36	182.63	100.4465
	6223 Sensor	0.19		
View M-M	1284303 Bracket	0.07	193.65	52.2855
	BZ2RQ1244A2 Switch	0.20		
View N-N	TRU-66A Press Switch	1.0	153.31	153.3100
Zone 10-H	1284309 Shelf	1.31	192.35	444.3285
	2101306 Designator	1.00		
Zone 10-H	1284295 Shelf	1.25	192.13	240.1625
Zone 11-E	1284304 Bracket	2.50	166.50	582.7500
	AN8-4 Transmitter	0.50		
	MS28034-1	0.50		
Zone 15-C	1284312 Panel	1.10	43.4	47.7400

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TABLE XIII. (Concluded)

Installation Drawing 1284296	Part Number		Wt (lb)	C.G. (in)	Moment (in-lb)
-----	2101040-1-1 DAU DAU Rack		14.70 4.20	199.63	3773.0070
-----	Pressure Hoses		3.50	200.00	700.0000
-----	Wires and Connectors		31.50	172.00	5418.0000
		Subtotal	74.90		13,692.1391
-----	2101038-1-1 CMU CMU Rack		18.50 4.20	192.37	4366.7990
		Total	97.60	185.03	18,058.9381
-----	2101042 Recorder Recorder Rack		11.00 4.20	192.37	2924.0240
		Total	90.10	184.42	16,616.1631

- Multiple implants in adjacent components should be tested in order to determine the discrimination capability of the system.

- The "flight safety" tests outlined were a misnomer and did not adequately demonstrate compatability with or isolation from the production instruments. The production parameter inputs to the AIDAPS system should be disconnected during helicopter ground operations and any change noted in the value of the appropriate aircraft instruments noted. An engine HIT check and/or TOPPING check with AIDAPS off and the AIDAPS EGT parameters disconnected should be conducted and the results compared with a HIT and TOPPING check conducted with the EGT parameters connected and the AIDAPS equipment operating.

- Airesearch indicated during the coordination meeting that it requires 5 minutes of steady state flight for the data acceptance cycle to indicate a gas path fault and 20 minutes of steady state flight to indicate a vibration fault. "Typical" nap-of-the-earth and formation flying mission profiles should be incorporated in the test plan as well as the "typical" supply mission profile outlined in the test plan to determine if AIDAPS will work under these conditions.

The Airesearch Phase V Coordinated Test Plan (Draft) 75-11738, dated 9 October 1975, was received 13 October 1975. The draft described the revised plan of accomplishment for the Airesearch bench and airborne tests of the prototype AIDAPS system prior to and during the development tests scheduled for Fort Rucker, Alabama. The test plan was reviewed and comments concerning the plan were submitted to AVSCOM in BHT Letter 1M:JHH:1M-3068, dated 23 October 1975, and are summarized as follows:

- An appendix presenting the Airesearch standard trouble reporting form mentioned in the first sentence and on Page 4-8 of the test plan was recommended.

- There is no explanation as to why the P/N 204-040-245 ball bearing Category "D" Implant BHC-104 was not considered properly categorized.

- Race spalling was described in the test plan for the hanger bearing, Implant BHT-122. The actual mode of degradation is unknown, as well as the category, until the bearing is disassembled. Upon disassembly the bearing will be destroyed.

- The artificially damaged 204-040-330 Sun Gear, Implant BHC-118, and the 204-040-700 Input Pinion, Implant BHC-119, are not considered valid implants. As noted in the BHT AIDAPS Monthly Progress Report No. 26 for July 1975:

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"Implant part numbers BHC-117 through BHC-121 inclusive were reserved for artificially degraded gear implants provided by Parks College through AVSCOM to Ft. Rucker, Alabama. The implants were apparently degraded by grinding grooves in the gear teeth. BHT considers that this method of artificially degrading gears is not indicative of a natural fault and should not be used for evaluating diagnostic signature data."

- Airesearch indicated that "any" flight profile may be flown during demonstration testing to evaluate the prototype AIDAPS system but indicated that each test flight should consist of at least ten sequentially different and stabilized power settings. The duration of stabilized operation should be "a couple of minutes" and the sequentially different power settings should differ in N_1 compressor speed by at least $\pm$ .5%. "Stabilized power" meant no change in collective setting or "large" changes in altitude or attitude. If these conditions are necessary, then a special maintenance flight profile will be required for the AIDAPS to properly function.

- The sketches indicating proper installation of bearing implant outer race defects included in the test plan were provided informally by BHT personnel in order to assist the mechanics and inspectors at Ft. Rucker, Alabama. The formal and official presentation of this data was provided in BHT Quarterly Letter Progress Reports, Numbers 4 and 5. It was requested that this appendix be removed from the Airesearch test plan and reference be made in the body of the report to the published information as required.

AVSCOM did not request any equipment installation reviews of the prototype AIDAPS installation as was conducted of the AIDAPS data collection installation. Implant information as outlined in Table II was requested and provided to Airesearch for incorporation as an appendix to their final draft coordinated test plan. Nap-of-the-earth and formation flying test profiles were incorporated as recommended in the draft of the USA ADTA "Advanced Development Verification Test - Government (ADVT-G) of the Automatic Inspection, Diagnostic, and Prognostic System (AIDAPS)" test plan.

Airesearch informally requested confirmation of the engine and transmission tachometer drive speeds. The following information was provided informally to Airesearch personnel:

- Engine Tachometer Speed = .6386 Engine Input Shaft Speed
  100% Engine Tachometer Speed = (.6386) 6600 RPM = 4214.76 RPM

- Transmission Tachometer Speed = .6516 Transmission Input Shaft Speed

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- 100% Transmission Tachometer Speed = (.6516) 6600 RPM = 4300.56 RPM

4.7 Inspection and Grading of Parts - Task VII

Selected degraded parts from overhaul facilities were provided by AVSCOM, inspected by BHT personnel, and the degradation classified into Categories "A" to "E" as outlined in Table XIV. Category "A" (no defect) parts were tested during the baseline signature data collection effort. Category "E" (failed) parts could not be tested. During the Reference (13) Coordination Meeting it was reported that Category "B" and "C" degradation was not detectable by the hardware contractor's vibration analysis. The degraded parts tested at the BHT facility for malfunction signature data and/or validated as flight test candidates for use by the AIDAPS hardware contractor at Ft. Rucker, Alabama were, as requested by AVSCOM, therefore in the upper limit "C" or "D" category. As a result, the diagnostic annunciation of the AIDAPS system, as reported in Reference (14) was set for upper limit "C" and "D" degradation level parts, in order to confidently detect degradation with a minimum of false alarms.

Very few UH-1H bearing implant candidates provided by AVSCOM were beyond the "B" category degradation. Most of the bearing implants tested were artificially degraded by means of a vibro etching tool. These parts were satisfactory for signature analysis; however, naturally degraded bearings with subsurface fatigue were required to conduct a valid degradation rate test for use in failure prognosis. Considerably more naturally degraded bearings were required than were available. Supplementary Agreement 06 to the subject contract and delivery order was received to authorize procurement of induced defective bearings. MAIC Division of the Pure Carbon Company, St. Marys, Pennsylvania, was awarded a subcontract to induce fatigue defects in the AVSCOM provided bearings.

The operating history of the degraded parts, including the test time at the BHT transmission test facility, the flight test time at Ft. Rucker, and word and picture descriptions are presented in Appendix E. The MAIC bearing degradation program is outlined as follows.

4.7.1 MAIC Operation of Bearings to Specified Degradation Criteria

The objective of the MAIC effort was to provide BHT with fatigued bearings with specified area spalling. The spalled bearings were subsequently used in the Removal Limit Confidence Test outlined in Section 4.8. Selected bearings stored at the U.S. Army Headquarters and Installation Support Activity, Granite City, Illinois, were shipped to MAIC for this program. The MAIC program was described in three tasks as follows:

TABLE XIV
DEGRADED PART CLASSIFICATION

BALL BEARING DEFECT CATEGORY

Category A - No defect.

Category B - Initial Spalling: One or more voids or irregularities in the ball path or on the ball itself not exceeding an area described by 0.05 x ball diameter wide or 0.20 x ball diameter long.

Category C - Moderate Spalling: One or more voids or irregularities in the ball path or on the ball itself between the upper limit of Category B and not exceeding an area described by 0.30 x ball diameter wide by 0.40 x ball diameter long.

Category D - Advanced Spalling: Bearing still operational, but with one or more voids or irregularities in the ball path or on the ball itself greater than the upper limit of Category C.

Category E - Functional Failure: Bearing jammed, or contains a broken component.

ROLLER BEARING DEFECT CATEGORY

Category A - No defect.

Category B - Initial Spalling: One or more voids or irregularities in the roller path or on the roller itself not exceeding an area described by 0.15 x roller diameter circumferentially or 0.30 x roller length axially.

Category C - Moderate Spalling: One or more voids or irregularities in the roller path or on the roller itself between the upper limit of Category B and not exceeding an area described by 0.30 x roller diameter circumferentially across the total width of the roller or roller path.

Category D - Advanced Spalling: One or more voids or irregularities in the roller path or on the roller itself greater than the upper limit of Category C.

Category E - Functional Failure - Bearing jammed, or contains a broken component.

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TABLE XIV (Continued)

GEAR DEFECT CATEGORY

Category A - No defect

Category B - Initial Pitting or Spalling or Light Scoring: Pits or spalls on a few teeth, generally less than 1/32 inch across the widest dimension and less than 0.010 inch in depth. If scored, scoring marks visually detectable, perpendicular to the pitch cylinder or cone.

Category C - Moderate Pitting, Spalling or Scoring: Pitting or spalling on one or more teeth whose total length spans 20 to 40 percent of the working face width of the gear tooth. Scoring of spur gears consisting of heavy lines detectable with a scribe, extending into the edge break of tooth tips, or creating a pattern across the flank of one or more teeth. Scoring of spiral bevel gears consisting of heavy lines detectable with a scribe, over 50 percent or more of the working surface of one or more teeth.

Category D - Advanced Pitting, Spalling or Scoring. Gear still capable of transmitting power, but with pitting or scoring over more than 40 percent of the working face width of one or more teeth. Scoring more extensive than for Category C, including displacement of base material.

Category E - Functional Failure: Tooth broken, gearset locked or inability to transmit power.

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- Task I: Engineering Evaluation

  A review of the dynamic and static load characteristics of the bearings was accomplished in order to establish load and RPM parameters to fatigue spall the bearings described in Table XV.

- Task II: Test Machinery

  The test adapters required to insert the bearings and apply the test loads determined from Task I were designed and fabricated.

- Task III: Test Operation

  The bearings described in Table XV were operated in the bearing test machinery designed in Task II to obtain upper limit Category "C" and "D" degradation as described in Table XIV.

The MAIC Division Report covering the Task I evaluation and the Task II design is presented in Appendix F. The bearings received from the MAIC Task III test operations are presented in Appendix E.

4.8 Limiting Part Conditions - Task VIII

Task VIII of the subject contract required BHT to evaluate UH-1H engine, transmission and gearbox part condition and failure modes and recommend the limit of wear or degree of abnormality allowed for parts and components while being monitored in AIDAPS equipped UH-1H aircraft. Part (a) of Task VIII required an initial evaluation for degraded parts or components operated at the U.S. Army Aircraft Development Test Activity (USAADTA), Ft. Rucker, Alabama, in the flight test data collection effort by the AIDAPS hardware contractor. Part (b) of Task VIII required a final evaluation for degraded parts and components that will be limiting in an actual fielded AIDAPS application.

4.8.1 UH-1H Engine Limiting Part Conditions

The Avco Lycoming Division was subcontracted to provide UH-1H engine related AIDAPS services. The limiting part conditions for degraded engine parts and components is a complete subject in itself and is presented in Reference (3).

4.8.2 Initial Limiting Part Conditions

UH-1H drive train parts were recommended by the contractor as possible flight test candidates for use in the flight test data collection effort by the AIDAPS hardware contractor at Ft. Rucker, Alabama. The rationale and procedures followed in the selection and test of parts were established in Reference (15) and are

TABLE XV
MAIC DEGRADATION PROGRAM BEARING REQUIREMENTS

Bearing Part Number	Sequence No. 1	Sequence No. 2	Sequence No. 3	Total
204-040-143	3	6	6	15
204-040-424	1	1	1	3
205-040-245	1	1	1	3
205-040-246	1	1	1	3
204-040-310	4	4	4	12
204-040-406	1	1	1	3
204-040-407	1	1	1	3
Total	12	15	15	42

summarized herein.

The levels of gear and bearing part deterioration used for the AIDAPS implant classification are presented in Table XIV. The initial inspection and grading of the parts to determine their classification was performed by BHT engineering personnel. Inspection and description data sheets were generated per Figures 22 and 23, documenting each implant and accompanying each implant from initial inspection and validation test through final flight test. The parts recommended as possible implant candidates were determined as a result of validation testing on the BHT test stand or in the UH-1H helicopter on the tiedown pad at Ft. Rucker, Alabama. At the conclusion of the part validation test the implant part was disassembled and inspected. If no additional degradation from either visual or recorded test data was exhibited, the implant candidate was recommended for either cell and flight test operations or cell test operations only based on the severity of degradation. The recommendation was noted on the implant data sheet. After inspection review by AVSCOM for flight safety release and operation restrictions, the implant was installed in an AIDAPS test transmission or gearbox and subjected to the appropriate helicopter ground maintenance procedures outlined in Appendix F and Reference (16). At the conclusion of test flights per the Airesearch test plan of Reference (17), the implant part was disassembled and inspected by USA ADTA and/or BHT engineering personnel, and a decision was made regarding release for further flight testing. The implant part inspection and data sheets were continuously updated to reflect this decision.

The above procedure controlled each individual implant candidate installed and flown in the AIDAPS equipped helicopters under controlled flight test operations by the USADTA flight crews at Ft. Rucker, Alabama. Flight operating restrictions considered prudent by the contractor were recommended in the implant part documentation. Recommendations made as a result of this procedure did not constitute safety-of-flight approval. The ultimate decision to flight test contractor recommended candidate parts or components for monitoring in test helicopters was at the sole determination and responsibility of the Government.

4.8.3 Limiting Part Condition for the AIDAPS Prototype Advanced Development Test.

A scarcity of naturally degraded parts restricted the amount of prognostic testing which could be accomplished. A subcontract to induce fatigue defects in the AVSCOM provided bearings was awarded to MAIC as reported in Section 4.7. These bearings supplemented the available naturally degraded bearings to be used in the Removal Limit Confidence Test conducted at BHT. This test is presented in detail in Reference (18).

The goal of this test was to establish a 6-hour reliability of

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IMPLANT PART
INSPECTION DATA SHEET

Sheet A-___

Initial ______________ After Test Run ______________ Date ________________

Nomenclature __________________________ Test P/N ____________________

P/N ______________________________________ Category A __ B __ C __ D __ E __

S/N ______________________________________ Implant Part Test Time ________

Recommended Use for Test: Cell Test Only _______ Cell and Flight Test ________

The recommendation in no way constitutes safety of flight approval. The ultimate decision for any flight release is at the sole determination and responsibility of the Government.

Degradation Type: Mode ______________ Natural _______ Artificial ___________

Removed From: Test Component No. ______________________ Date ______________

Component P/N ______________________ S/N ____________________

Cell No. ______________/ AC: Type ___H-1___ : Tail No. ____________

Reason for Removal ____

Description Data Sheets and Photographs __________________________________

Installed in: Test Component No. ____________________ Date ________________

Component P/N ______________________ S/N ____________________

Cell No. ______________/ AC: Type ___H-1___ : Tail No. ____________

Installation Notes, Recommended Operating Restrictions, and Photographs ________

Test Log:

Test Run	Date	Operating Time	Data Log References and Comments

Total Implant Part Test Time ______________

Compiled by: ______________________________ Department: ________________

Figure 22. Implant part inspection data sheet.

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IMPLANT PART
DESCRIPTION DATA SHEET

Sheet B-____

INITIAL ______________________ TEST PART NO. ______________________

AFTER TEST RUN ________________ DATE ______________________

Degradation Description:

(Include photographs as required. Note any changes from previous inspections and any qualitative engineering evaluation that may have a possible impact on data.)

Compiled by: ______________________ Department: ______________

Figure 23. Implant part description data sheet.

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at least 95% with a 90% confidence level. Six hours exceeds the maximum endurance limit of the UH-1H helicopter and provides an adequate block of test time for implants to be test flown during the AIDAPS Prototype Advanced Development Tests at USAADTA, Ft. Rucker, Alabama. The reliability determination, as outlined in Reference (19), shows that 45 tests without failures are required to demonstrate 95% reliability with a 90% confidence level. Multiple implants were installed and operated concurrently in order to keep the test time to a reasonable level. Only three sets of transmission and gearbox parts were available; so for test and analysis purposes, it was planned to operate each set of parts for a minimum of 90 hours. Each 90-hour test would then be considered as fifteen 6-hour tests. Table XVI shows the implants installed for the three test build-ups of the drive train, the total number of 6-hour test cycles on each implant, and the test results of the Removal Limit Confidence Test. The 6-hour reliability was determined for a 90% confidence level from Table A.1 of Reference (19) for no part failures, or from Table A.3 of Reference (19) with part failures experienced. The results indicate that, as tested, a level of confidence appeared satisfactory to operate implant parts with the degradation levels required by Airesearch in Reference (14)(with the exception of the transmission planet roller bearings) during the AIDAPS Prototype Advanced Development Test at Ft. Rucker. Excessive secondary damage was experienced when category "C" or "D" planet rollers were implanted.

4.8.4 Fielded AIDAPS Application Limiting Part Condition

The fatigue induced degraded parts operated during the transmission and gearbox data collection effort at the BHT transmission test facility and during the flight test data collection effort at Ft. Rucker, were evaluated and described in Reference (18) in order to recommend limiting part conditions for an actual fielded application. The operating history of the fatigue induced degraded parts was compiled as presented in Appendix E. The implant part reliability was calculated using the methods outlined in Reference (19).

The test cycles required for a 95% reliability at the 90% confidence level were determined from Table A.1 and Figure A.3 of Reference (19). The reliable life for each part was calculated and is presented in Table XVII. The results do not indicate a level of confidence that upper limit "C" to "D" classified part removal thresholds (required by the AIDAPS hardware to confidently detect degradation with a minimum of false alarms per Reference (14)) occur prior to failure by an adequate margin for an operationally fielded AIDAPS helicopter.

The test time and naturally degraded parts required to run a statistically adequate comprehensive prognostic reliability test were

AD-A055 385 BELL HELICOPTER TEXTRON FORT WORTH TEX F/G 14/2

AUTOMATIC INSPECTION, DIAGNOSTIC AND PROGNOSTIC SYSTEM (AIDAPS)--ETC(U)

AUG 77 J V HICKEY DAAJ01-71-A-0335

UNCLASSIFIED USAAVRADCOM-TR-78-4 NL

2 OF 5

AD A055385

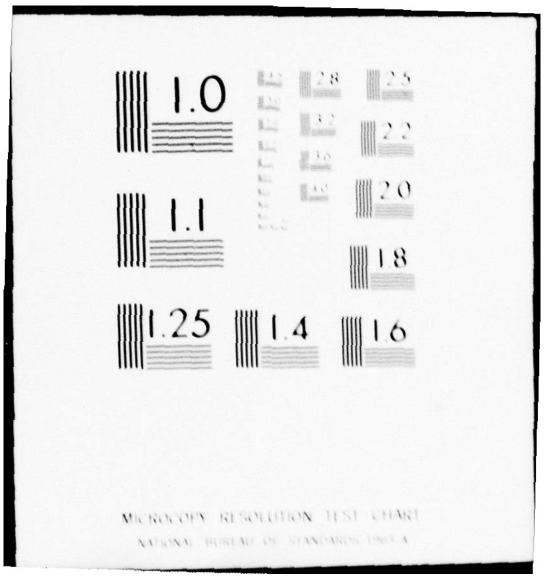
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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TABLE XVI

REMOVAL LIMIT CONFIDENCE TEST

RELIABILITY TEST RESULTS

Component			Implant Data		Results				
Description	Build	Part Number	Implant	Defect	No. 6 Hour Cycles	Cycles @ Failure	Total Cycles	Total Failures	6 Hour Life Reliability (%) @90% Confidence
42° Gearbox									
Input Duplex Ball Brg	1	204-040-143-1	B001	"D" O/R Spall	15		47	0	95
	2		M010	"D" Ball Spall	15				
	3		M027	"C" I/R Spall	17				
Input Roller Brg	1	204-040-310-1	M007	"C" O/R Spall	15		47	0	95
	2		M009	"D" I/R Spall	15				
	3		M008	"D" Roller Spall	17				
Gearset	1	204-040-500-9	B109/10	"D" Score	7	7	47	2	89
	1	-10	B127/28	"D" Score	8	8			
	2		B111/12	"D" Score	15				
	3		B134/35	"D" Score	17				
Output Duplex Ball Bearing	1	204-040-143-1	M002	"C" I/R Spall	15		47	0	95
	2		M011	"C" I/R Spall	15				
	3		M028	"D" I/R & O/R Spall	17				
Output Roller Brg	1	204-040-310-1	M008	"D" Roller Spall	15		47	0	95
	2		M021	"D" I/R Spall	15				
	3		M007	"C" O/R Spall	17				
90° Gearbox									
Input Duplex Ball	1	204-040-143-1	M001	"D" Ball Spall	15		47	1	92
	2		M012	"D" I/R Spall	15				
	3		M026	"D" I/R Spall	9	9			
	3		M003	"D" I/R Spall	8				
Input Roller Brg	1	204-040-406-1	M006	"D" Roller Spall	15		47	1	92
	2		M019	"D" I/R & O/R Spall	15	15			
	3		M031	"D" I/R & Roller Spall	9	9			
	3		M006	"D" Roller Spall	8				
Gearset	1	204-040-400-9	B113/14	"D" Score	15		47	0	95
	2	401-7	B101/02	"D" Score	15				
	3		B136/37	"D" Score	9				
	3		B033/34	"C" Score	8				
Output Duplex Ball Brg	1	204-040-424-1	M005	"C" O/R Spall	10		42	0	94
	2		M016	"D" O/R Spall	15				
	3		M030	"C" I/R Spall	17				
Output Roller Brg	1	204-040-407-3	----						
	2		M020	"D" O/R Spall	15		32	0	93
	3		M023	"D" O/R Spall	17				

TABLE XVI. (Cont'd)

Component			Implant Data		Results				
Description	Build	Part Number	Implant P/N	Defect	No. 6 Hour Cycles	Cycles @ Failure	Total Cycles	Total Failures	6 Hour Life Reliability (%) @90% Confidence
Transmission									
Sump Input Gear	1 & 2	204-040-103-7	B131	"C" Score	30		30	0	92
T/R Drive Gear	1 & 2	204-040-104-13	B130	"C" Score	30		30	0	92
Input Triplex Ball Brg	1	205-040-246-3	B068	"C" Ball Spall	15		47	0	95
	2		M018	"C" I/R Spall	15				
	3		M025	"C" I/R Spall	17				
Input Pinion	1	204-040-700-1	B115	"D" Score	15		47	0	95
	2		B036	"D" Score	15				
			B138	"D" Score	17				
Input Bevel Gear	1	204-040-701-3	B116	"D" Score	15	30	47	1	92
	2		B037	"D" Score	15				
	3		B139	"D" Score	17				
Gearshaft Duplex Ball Brg	1	205-040-245-1	B039	"D" O/R & Ball Spall	15	15	47	1	92
	2		M017	"D" I/R Spall	15				
	3		M024	"D" Ball Spall	17				
Upper Sun Gear	1	204-040-330-3	B038	"D" Score	15	30	0		92
	2		B050	"D" Spall	15				
	3		----						
Upper Planet Gear	1	204-040-108-7	B079	"C" Chip	15	30	0		92
	2		B083	"C" Debris	15				
	3		----						
Lower Planet Roller	1	204-040-725-1	B073	"C" Rollers (Rough) (2)	15	15	30	2	83
	2		B071	"D" Roller Spall	15	15			
	3		----						
Upper Planet Inner Race	1	204-040-132-1	B126	"D" Spall	15		15	0	86
	2		----						
	3		----						
Upper Mast Brg	1	204-040-136-7	B123	"D" O/R, IR Ball Spall	15		47	0	95
	2		B124	"D" O/R Spall	15				
	3		B132	"C" O/R Spall	17				
Offset Quill Duplex Ball Brg	1	204-040-143-1	M003	"D" I/R Spall	15		47	0	95
	2		M014	"D" I/R Spall	15				
	3		M010	"D" Ball Spall	17				
Sump Quill Duplex Ball Brg	1	204-040-143-1	M004	"D" I/R Spall	15		47	0	95
	2		M015	"D" I/R Spall	15				
	3		M012	"D" I/R Spall	17				

TABLE XVI. (Concluded)

Component			Implant Data		Results				
Description	Build	Part Number	Implant P/N	Defect	No. 6 Hour Cycles	Cycles @ Failure	Total Cycles	Total Failures	6 Hour Life Reliability (%) .90% Confidence
Transmission (Cont'd)									
Sump Quill Roller Brg	1	204-040-310-1	----				32	0	93
	2		M007	"C" O/R Spall	15				
	3		M021	"D" I/R Spall	17				
T/R Quill Duplex Ball Brg	1	204-040-143-1	B008	"C" O/R Spall	15		47	0	95
	2		M013	"D" I/R Spall	15				
	3		M011	"D" I/R Spall	17				
T/R Quill Roller Brg	1	204-040-310-1	M009	"D" I/R Spall	15		47	0	95
	2		M008	"D" Roller Spall	15				
	3		M009	"D" I/R Spall	17				

TABLE XVII
DEMONSTRATED RELIABLE LIFE
(95% RELIABILITY @90% CONFIDENCE)
NATURALLY DEGRADED AIDAPS TRANSMISSION AND GEARBOX IMPLANTS

Implant P/N	Test Hours	Failures	Cycles Required	Demonstrated Reliable Life (Hours)
204-040-143 Ball Bearing				
BHC-001	241.5			
BHC-003	10.3			
BHC-007	69.1			
BHC-008	128.2			
BHC-018	102.0	X		
MAIC 001	91.8			
MAIC 002	91.8			
MAIC 003	135.7			
MAIC 004	91.8			
MAIC-010	192.1			
MAIC-011	192.1			
MAIC-012	192.1			
MAIC-013	90.1			
MAIC-014	90.1			
MAIC-015	90.1			
MAIC-026	58.1	X		
MAIC-027	102.0			
MAIC-028	102.0			
Total	1985.3	2	105	18.9
205-040-245 Ball Bearing				
BHC-039	91.8	X		
MAIC-017	90.1			
MAIC-024	102.0			
Total	283.9	1	75	3.8
204-040-424 Ball Bearing				
MAIC-005	62.1			
MAIC-016	90.1			
MAIC-030	102.0			
Total	254.2	0	45	5.7

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TABLE XVII (Continued)

Implant P/N	Test Hours	Failures	Cycles Required	Demonstrated Reliable Life (Hours)
204-040-310 Roller Bearing				
MAIC-007	283.9			
MAIC-009	283.9			
MAIC-021	192.1			
Total	759.9	0	45	16.9
204-040-406 Roller Bearing				
MAIC-006	135.7			
MAIC-019	90.1	X		
MAIC-031	58.1			
Total	283.9	1	75	3.8
204-040-407 Roller Bearing				
MAIC-020	90.1			
MAIC-023	102.0			
Total	192.1	0	45	4.3
204-040-725 Planet Roller				
BHC-071	91.9	X		
BHC-073	93.6	X		
Total	185.6	2	105	1.8
204-040-132 Planet Race				
BHC-126	91.8	X	45	2.1
204-040-136 Mast Bearing				
BHC-052	9.0			
BHC-123	91.8			
BHC-124	90.1			
BHC-132	102.0			
Total	292.0	0	45	6.5

TABLE XVII (Continued)

Implant P/N	Test Hours	Failures	Cycles Required	Demonstrated Reliable Life (Hours)
205-040-246 Triplex Bearing				
MAIC-018	90.1			
MAIC-025	102.0			
BHC-068	93.6			
Total	285.7	0	45	6.4
204-040-500-9 42° GB Pinion				
BHC-004	12.5			
BHC-015	6.2			
BHC-017	5.9			
BHC-019	50.9	X		
BHC-111	106.7			
BHC-127	98.0			
BHC-134	102.0			
Total	332.0	2	105	3.2
204-040-500-10 42° GB Gear				
BHC-016	5.9			
BHC-110	50.9			
BHC-112	106.7			
BHC-128	48.0			
BHC-135	102.0			
Total	313.5	0	45	6.9
204-040-400 90° GB Pinion				
BHC-029	6.5			
BHC-033	51.5			
BHC-101	222.7			
BHC-113	99.2			
BHC-136	58.1			
Total	438.0	0	45	9.7

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TABLE XVII (Concluded)

Implant P/N	Test Hours	Failures	Cycles Required	Demonstrated Reliable Life (Hours)
204-040-700 Xmsn Input Pinion'				
BHC-036	103.3			
BHC-044	8.0			
BHC-051	1.7			
BHC-115	91.8			
BHC-138	102.0			
Total	306.8	0	45	6.8
204-040-103 Xmsn Sump Gear				
BHC-075	1.8			
BHC-131	181.9			
Total	183.7	0	45	4.1
204-040-104 TR Output Gear				
BHC-069	1.8			
BHC-130	181.9			
Total	183.7	0	45	4.1
204-040-108 Xmsn Planet Gear				
BHC-079	98.1			
BHC-083	91.8			
Total	189.9	0	45	4.2
204-040-330 Xmsn Sun Gear				
BHC-038	106.2			
BHC-048	11.9			
BHC-050	92.5			
BHC-105	120.5			
Total	331.1	0	45	7.4

beyond the scope of the allowable schedule or parts available. For example, MAIC operated bearings in groups of seven around the clock for five months, and only supplied 34 bearings for use in the Removal Limit Confidence Test. In order to set reliable and realistic degradation levels in a fielded application, a prognostic field test with a diagnostic system that has the capability to detect initial degradation in the "B" category should be conducted with sufficient aircraft to provide a statistically adequate number of data points. The diagnostic removal limits can thus be set low and continuously updated to the highest practical limit as confidence is assured that the limits can safely be increased.

4.8.5 Limitations

Any conclusions or recommendations made as a result of this report shall not constitute or imply safety-of-flight approval. The ultimate decision to fly degraded parts shall be at the sole determination and responsibility of the Government.

4.9 Engineering and Technical Support - Task IX

4.9.1 Ground Run Procedures and Equipment

It was agreed during the initial AIDAPS coordination meetings that all drive train components used in the program should be verified as being in a "no-defect" condition prior to baseline data collection. This was accomplished by subjecting each component to a teardown, inspection, green run, and reinspection. Components operated in the BHT test stand were verified by BHT, and those operated at Fort Rucker were verified by USAADTA. Teardown and inspection procedures were followed per the following UH-1H Work Requirements:

Work Requirement	Component
DMWR 55-1615-156	Universal Transmission
DMWR 55-1615-155	Transmission Quills
DMWR 55-1560-127	90-degree Gearbox
DMWR 55-1560-123	42-degree Gearbox

Standard BHT Acceptance Test Specification green run procedures were followed at BHT. These procedures were modified by BHT for use by USAADTA at Ft. Rucker, in order for the green runs to be conducted on components installed in a tied-down helicopter. These procedures are contained in Appendix G.

Following baseline condition verification and data collection, various discrepant parts were installed in the test components for signature data collection. In these cases, a short maintenance run-in was performed on the aircraft tiedown pad before flight release, to minimize the risk of the implanted part failing in flight. Tiedown runs were also used to collect data on

parts which were judged unsuitable for flight.

BHT recommended tiedown operation procedures were provided to USAADTA, as shown in Appendix G. A 212-HES-290-1 stick limiter tool and a 204-900-01-WHT-1 tiedown tool were also provided on loan. Data for fabrication and installation of the remaining tiedown equipment was provided as follows:

Part Number	Sketch Number	Title
212-038-029		Tiedown Requirements
	205-HES-279	Skid Gear Restraint Hook
204-031-464		Tiedown Shackle
	212-HES-295	Tiedown Fitting

Recommendations for AH-1G tiedown run operation were released via BHT Letter 81:JVH:peb/rcn-54, dated 5 February 1975 and are presented in Appendix G.

4.9.2 Input Driveshaft Failures During Ground Runs

Several input driveshaft failures were experienced during early UH-1H tiedown runs at Fort Rucker. The problem was researched by BHT, and recommended procedures for avoiding such failures were developed and submitted via BHT Letter 80:JVH:dhw-337, 4 December 1973. Special transmission mounts and lift link for tiedown operation were provided by BHT on loan. The installation of this special equipment is described in Appendix G.

4.9.3 Bearcat 13 Vibration Problem

BHT assistance was requested by AVSCOM with regard to excessive medium frequency vibration of AIDAPS helicopter "Bearcat 13" (a UH-1H) in flight. The aircraft had completed depot repair at ARADMAC after 4000 flight hours, and subsequently had been converted from a "D" model to an "H" model. It had then been assigned to Aberdeen Proving Grounds, where it was used for approximately 500 hours of various weapon system tests, following which it was assigned to the AIDAPS program. BHT informally provided a list of structural and control system inspections and rotor adjustments for investigation. Telephone consultations between Hawthorne Aviation personnel at Fort Rucker and BHT Service Engineers failed to solve the problem, and AVSCOM was advised that the next step would be to request that a BHT service engineer investigate the problem on-site. AVSCOM did not request further assistance, but indicated that Bearcat #13 would be removed from the flight test program.

4.9.4 Ground Run Oil Temperature Problem

The Army Aviation Test Board informed Bell Helicopter Textron (BHT), that with an outside air temperature of 90°F or above, the maximum gearbox oil temperature of 212°F was reached after

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fifteen minutes of tiedown operation. An alternate test cycle was outlined and formally presented to the Test Board per BHT Letter 80:JVH:dhw-30, dated 14 June 1974. The procedure is presented in Appendix G.

4.9.5 Hydraulic Pad Implant

Airesearch requested that a 204-040-143 bearing be implanted in a 204-040-367 Hydraulic Pump and Tachometer Drive Quill Assembly. The USAAVSCOM DMWR 55-1615-155 Work Requirement for disassembly and reassembly of the quill was discussed per telephone conversation between BHT and Hawthorne Aviation personnel. No problem with disassembly or reassembly of the quill was encountered.

4.9.6 Engine Operating Procedure Change

An engine operating caution note indicating that the N_2 speed should be maintained above 5500 RPM was added per Change 8 to the TM-55-1520-210-10 Operator's Manual, dated 25 August 1971. Recommended changes to the ground run tiedown procedures for the AIDAPS test aircraft at Ft. Rucker, Alabama, to comply with the caution note were submitted to AVSCOM in BHT Letter 81:JVH:peb-177, dated 3 September 1975.

4.9.7 Increased Transformer Capacity

The 28 VAC/150 VA transformer, P/N 209-075-363, was recommended to replace the production 28 VAC/50 VA transformer, P/N 9T39Y5, for the prototype AIDAPS equipped helicopters. Detailed installation information was presented to AVSCOM, per BHT Letter 81:JVH:peb-194, dated 12 September 1975, and is outlined in Appendix G.

4.9.8 Cargo Sling Fitting Failures

A broken 205-030-107-1 cargo sling fitting was received from Fort Rucker, Alabama. This fitting is used as the attachment point for the tiedown tool for AIDAPS UH-1H helicopters while operating on the tiedown pad at Fort Rucker. The broken fitting was examined by BHT personnel. The findings of the examination were presented to AVSCOM per BHT Letter 81:JVH:peb-194, dated 12 September 1975, and are contained in Appendix G.

A second 205-030-107-1 cargo sling fitting was reported as having failed at Fort Rucker after incorporation of the procedures outlined in BHT Letter 81:JVH:peb-194. The fitting apparently failed in fatigue similar to the previous fitting failure reported. Further investigation at Fort Rucker indicated that the fitting was installed backwards. In order to reduce the possibility of further fatigue failures during tiedown operations, the Ft. Rucker personnel were advised to replace the

production 7075-T6 aluminum forged fitting with a more fatigue resistant fitting manufactured from 4340 steel, heat treated to 125,000 psi. The steel fitting was fabricated and installed at Ft. Rucker, and no further failures were reported.

4.10 Technical Representation - Tasks X, XI, and XII

AVSCOM anticipated extensive trip requirements to provide technical assistance at sites other than at the Bell Helicopter Textron complex. The engine related services were subcontracted to the Avco Lycoming Div. in Stratford, Connecticut. Task X covered the trips required for the co-ordination effort between BHT and Lycoming. The flight test data collection effort was conducted at the United States Army Aviation Development Test Activity at Cairn's Field, Ft. Rucker, Alabama. Task XI covered the trips required to assist the USAADTA personnel with the instrumentation installation, implant part teardown and inspection, and operation of the helicopter on the tiedown pad as well as flight testing the AIDAPS hardware. The implant candidate parts were obtained from the Corpus Christi Army Depot and stored at the U.S. Army HQ and Installation Support Activity, Granite City, Illinois. Part (a) of Task XII covered the trips to these locations in support of the Task VII inspection and grading of parts effort described in Section 4.7. The Garrett Airesearch Manufacturing Company AIDAPS hardware contractor and the MAIC Division of the Pure Carbon Company are located in Torrance, California, and St. Marys, Pennsylvania, respectively. Part (b) of Task XII covered the trips required to co-ordinate the AIDAPS installation in the BHT helicopters (Section 4.9), and the trips required to co-ordinate the bearing degradation effort described in Section 4.7. The trip dates, BHT personnel affected and the purpose of the trips are summarized in Table XVIII.

4.11 Training Schools

4.11.1 Airframe Training

A special three-day course covering UH-1H aircraft systems was provided by BHT for AIDAPS personnel. The course was conducted on 11, 12, and 13 February 1974 at the BHT Training Center, and was attended by ten persons representing Airesearch, AVSCOM, Test Board, Lycoming, BHT, and Army National Guard (which provided a UH-1H helicopter for use as a training aid).

4.11.2 Engine Training

Arrangements were made by BHT for Avco Lycoming to provide engine training for AIDAPS personnel. A T53-L-13B Engine School was conducted on 7, 8, and 9 January 1974 at the Lycoming factory school.

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TABLE XVIII

SUMMARY OF OFF-SITE TECHNICAL REPRESENTATION

Date	BHT Personnel	Location	Purpose
14 June 73	W. D. Laingor J. A. Murphy	AVCO Lycoming Stratford, Conn.	Initiate subcontract effort for engine testing.
18-20 July 73	D. Y. Cleveland J. V. Hickey L. J. Hopfensberger W. D. Laingor J. A. Murphy	AVSCOM St. Louis, Mo.	Initial AIDAPS organizational meeting.
14-15 August 73	J. V. Hickey W. D. Laingor	Ft. Rucker	AIDAPS Co-ordination Meeting.
29 August 73	J. A. Murphy	AVCO Lycoming	AIDAPS Co-ordination Meeting.
11-13 Sept 73	J. V. Hickey W. D. Laingor J. A. Murphy	Airesearch Torrance, Calif.	AIDAPS Co-ordination Meeting.
15 Oct 73 to 5 Nov 73	J. V. Hickey	Ft. Rucker	AIDAPS Co-ordination Meeting. Assist in data collection system installations.
7-10 Jan 74	J. A. Murphy	AVCO Lycoming	Engine training school and AIDAPS Co-ordination Meeting.
7-18 Jan 74	J. V. Hickey	Ft. Rucker	Observe initial tiedown operations and procedures.
11 March 74	D. V. Cleveland	Airesearch	Observe interface with BHT data tapes and Airesearch data reduction.facilities.

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TABLE XVIII (Continued)

Date	BHT Personnel	Location	Purpose
12-14 Mar 74	W. D. Laingor J. A. Murphy	Airesearch	AIDAPS Program Review and Co-ordination Meeting.
11 April 74	J. A. Murphy	AVCO Lycoming	Engine Program Review.
18 April 74	J. P. Keating W. D. Laingor	AVSCOM	Discussion of UH-1H Reliability.
30 April to 1 May 74	J. V. Hickey J. A. Murphy R. B. Patten	Ft. Rucker	AIDAPS Program Planning and Co-ordination Meeting.
23 May 74	A. L. Eubanks D. S. Glass W. D. Laingor R. B. Patten	Airesearch	AIDAPS Data Review.
3&4 June 74	J. A. Murphy	AVCO Lycoming	Engine program planning and review.
16 July 74	J. H. Drennan W. D. Laingor J. A. Murphy	Airesearch	AIDAPS Advanced Development Review Meeting.
29&30 Jul 74	W. D. Laingor J. A. Murphy	Airesearch	AIDAPS test cell data requirements interface with flight test data requirements.
12-16 Aug 74	J. H. Drennan J. V. Hickey	Ft. Rucker	Review AIDAPS implant procedures and observe and review tiedown procedures.
11-13 Sept 74	J. H. Drennan J. V. Hickey	AVSCOM	Review of implant candidates and requirements.

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TABLE XVIII (Continued)

Date	BHT Personnel	Location	Purpose
19 September 74	J. A. Murphy	Airesearch	AIDAPS Co-ordination Meeting.
19-20 Sept 74	J. V. Hickey	CCAD Corpus Christi, Texas	Review of implant candidates and requirements.
31 October to 1 November 74	J. A. Murphy R. B. Patten	Airesearch	AIDAPS fault logic review meeting.
13 November 74	W. D. Laingor J. A. Murphy	AVSCOM	Test cell data requirements, planning and scheduling meeting.
11-12 Dec 74	J. V. Hickey	Ft. Rucker	Review implant condition tie-down operation and teardown inspection before flight release.
14-15 Jan 75	R. B. Patten	Ft. Rucker	Evaluate hydraulic pump case drain flow meter during helicopter flight test operations.
15 January 75	W. D. Laingor J. A. Murphy	AVSCOM	Test cell data requirements, planning and scheduling meeting.
6 February 75	J. A. Murphy	Airesearch	AIDAPS Co-ordination Meeting.
23 to 25 Apr 75	J. V. Hickey	AVSCOM	Review of implant candidates.
13 to 15 May 75	J. V. Hickey	CCAD	Test the Arkwin Flow Monitor and review implant candidates.
22 July to 1 August 75	J. V. Hickey	Ft. Rucker	Provide technical assistance during ground test runs on improper installation test candidates outlined in Appendix C.

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TABLE XVIII (Concluded)

Date	BHT Personnel	Location	Purpose
21 Aug 1975	J. V. Hickey J. A. Murphy	Airesearch	AIDAPS Co-ordination Meeting.
19&20 Nov 75	J. V. Hickey	Ft. Rucker	Review of implant candidates for the AIDAPS Prototype Testing.
27 April 76	J. V. Hickey J. A. Murphy R. B. Patten	Ft. Rucker	AIDAPS Program Review and Equipment Demonstration.
23-27 May 76	J. V. Hickey	Ft. Rucker	Review chip detector data @ USAAVS and discuss BHT interface with the USAADTA personnel during the AIDAPS Prototype Testing.
19-23 July 76	C. Bott J. V. Hickey	Ft. Rucker	Demonstrate the BHT high frequency demodulation gear and bearing detector analysis technique to USAAMRDL and USAADTA personnel.

5.0 CONCLUSIONS

The data collection effort expended during the course of this contract was very successful in providing a base for continuing development of a total aircraft inspection and diagnostic system and providing an insight into the tremendous effort required to develop a prognostic helicopter monitoring system.

The K-West, Franklin Institute Capacitative, Environment One and Nucleonic oil monitor systems were not conclusively evaluated due to test conditions, monitor system malfunctions, and other circumstances. However, positive results were obtained from the advanced chip detector systems. The test results indicate that an oil system debris transducer can provide trend analysis information, reduce false indications and the resultant precautionary landings required. The upper mast bearing debris collector trapped the debris from a discrepant bearing, preventing possible debris damage to other parts of the transmission and allowing the debris to collect at a discrete chip detector location to provide a warning of the bearing degradation. If each quill location within the transmission were designed with an oil collector and discrete advanced chip detector warning system, it is conceivable that unnecessary transmission removals would be decreased, the teardown inspections minimized and considerable maintenance cost savings realized, not to mention the debris protection provided to the remaining dynamic components.

The Arkwin flow monitor as tested in the hydraulic pump bypass circuit indicated that increasing hydraulic oil flow is a positive candidate for an inspection, diagnostic and prognostic hydraulic pump health monitor.

The analysis of the vibration tape data in order to insure that useable tape data was being generated led to investigating signal conditioning methods to isolate the gear and bearing vibration signatures, as discussed in Section 4.4. The demodulation techniques indicate that the concepts are technically feasible, simple to implement, and demonstrate considerable potential.

The vibration demodulation techniques tested demonstrated that a baseline signature is not required and that initial bearing degradation in the "B" category can be detected. The Equipment Performance Reports received during the prototype AIDAPS equipment demonstration at Ft. Rucker, Alabama, show that it requires an average of 9.8 hours of special steady state condition profile flying per aircraft to establish a mature baseline for a set of engine, transmission and gearbox components. The BHT demodulation technique relies on the physics of the transmission and gearbox design, eliminating the costly baseline signature determination. The demodulation technique is also much more easily adaptable to design changes within a given drive train,

or to other transmission systems, than is the AIDAPS prototype technique. With the BHT concept a simple adjustment of frequencies monitored within the detection circuit would be all that is required to adapt the monitor to another gearbox or for a bearing or gear design change made within the monitored gearbox.

The AIDAPS hardware developer reported that Category "B" and "C" degradation was not detectable by the AIDAPS vibration analysis. The degraded parts tested at the BHT facility for malfunction signature data and/or validated as flight test candidates for use by the AIDAPS contractor at Ft. Rucker, Alabama, were, as requested by AVSCOM, therefore in the upper limit "C" or "D" category. As a result, the diagnostic annunciation of the AIDAPS system is set for upper limit "C" and "D" degradation level parts, in order to confidently detect degradation with a minimum of false alarms. The parts collected from the overhaul facilities by AVSCOM to be used in this program were mostly in the "B" category degradation. A great amount of time was dedicated during the subject contracted program to artificially degrade implants and validate them in the BHT test cell in order to adequately support the flight test data collection effort conducted by the AIDAPS hardware contractor at Ft. Rucker.

Most of the bearing implants tested were artificially degraded by means of a vibro-etching tool. These parts were satisfactory for signature analysis; however, naturally degraded bearings with subsurface fatigue were required to conduct a valid degradation rate test for use in failure prognosis. The scarcity of such naturally degraded components restricted the amount of prognostic testing which could be conducted in a reasonable time. AVSCOM, BHT and the AIDAPS hardware contractor agreed that one primary part in the most probable failure mode would be implanted in the transmission and each gearbox and operated for 120 hours in the failure prognosis Degradation Rate Test.

The AIDAPS contractor reported that the changes in part condition during the 120-hour prognostic Degradation Rate Test conducted at BHT and the engine prognostic testing conducted at Avco Lycoming were inadequate to warrant analysis of the data. As a result, no prognostic capability was provided in the prototype AIDAPS system.

The reliable life determination calculations require 45 tests without failure to show 95% reliability at the 90% confidence level, and 75 and 105 tests for 1 and 2 failures respectively.

An uncompromised test for one bearing and one gear would therefore require 135 bearing implants (45 outer race, inner race and rolling element defects) and 45 gear implants tested for the required number of hours without failure. If a failure occurred, then 30 more implants with the same type of defect would be required. Seventeen bearing and ten gear locations were outlined

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to be tested in the UH-1H transmission and gearboxes. This would require a minimum of 2,745 implants if all three bearing defect types were tested or a minimum of 1,215 implants if only one bearing defect was tested. To further complicate the test planning, only one implant per location should be tested so that the defect degradation rate would not be affected by an adjacent defect.

The test time and the naturally degraded parts required to run a statistically adequate comprehensive prognostic reliability test became beyond the scope of the allowable schedule of parts available. The MAIC program, to supply fatigue induced defects for the Removal Limit Confidence Test, operated bearings in groups of seven, using three test rigs, around the clock for five months in order to degrade 34 bearings.

In order to gain an insight into the probable degradation rate and gain confidence in the part life remaining for use in the AIDAPS Advanced Development Test Program, the Removal Limit Confidence Test was designed and operated in the BHT transmission test laboratory. The results indicate that, as tested, a level of confidence appears satisfactory to operate implant parts with the degradation levels required by the Airesearch Manufacturing Company during the AIDAPS Prototype Advanced Development Test at Fort Rucker, Alabama. This conclusion is based on the premise that the AIDAPS implant bearings and gears will be operated by USA ADTA personnel under closely controlled flight test conditions. These conditions include:

- Detailed visual and magnaflux inspection of the implants.
- Preflight tiedown validation runs as outlined in the special maintenance guides developed for this program by BHT and USAADTA personnel.
- Operation of the aircraft by highly experienced and skilled aviators.
- Depot maintenance level postflight teardown inspections by highly experienced and skilled mechanics.
- Maintenance of the AIDAPS monitoring equipment by a highly qualified AIDAPS contractor technician.

The results do not therefore indicate a level of confidence that upper limit "C" to "D" classified part removal thresholds occur by an adequate margin prior to failure for an operationally fielded AIDAPS helicopter.

In order to set reliable and realistic degradation levels in a fielded application, a prognostic field test will be required with a diagnostic system, as developed at BHT during this program, that has the capability to detect initial degradation in the "B" category. The program will require sufficient aircraft to provide a statistically adequate number of data points under similar closely controlled flight test conditions that prevailed during the AIDAPS flight test program conducted by the USA ADTA personnel at Ft. Rucker, Alabama. The diagnostic removal limits can then be set low and continuously updated to the highest practical limit as confidence is assured that the limits can safely be increased.

A large engineering and technical support effort was required to provide technical problem solving expertise by the engine and airframe contractor. The field problems solved were highly dependent on the expertise and experience gained by previous programs, especially during the conduct of the helicopter tiedown operations, and engine MET stand operations. Knowledge of the helicopter vibration and temperature environment, and system parameter logic, provided valuable time saving recommendations by BHT and Lycoming personnel during equipment installations and in solving data reduction problems. The need for the airframe and engine manufacturers to share responsibility in the engineering management of a diagnostic or prognostic monitoring development program and the need for the manufacturer to have prime responsibility in the design of a production monitoring system suitable to their particular helicopter and/or engine configuration was demonstrated conclusively by the engineering and technical support required during this program.

6.0 RECOMMENDATIONS

It is recommended that a follow-on program to further define the inspection and diagnostic techniques developed during this program, and especially to develop prognostic capabilities, be initiated with the AIDAPS UH-1H helicopters presently based at the USAADTA, Ft. Rucker, Alabama. This can be accomplished by a TBO extension type program with serviceable transmissions, gearboxes and engines that are ready for time based overhaul. The serviceability can be established by teardown analysis using the personnel trained and the facilities developed at USAADTA, Ft. Rucker, Alabama, for the AIDAPS flight test data collection program. The BHT engineering tasks recommended to support this program are as follows:

- Design and fabricate a bearing and gear demodulation data collection and monitor system for the UH-1H helicopter.
- Design and fabricate debris collectors deemed feasible for installation within the transmission.

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- Procure advanced chip detectors and design and fabricate airworthy data collection and monitor systems.

- Design and fabricate a mechanical systems data collection and monitoring device based on the fault logic diagrams presented in Appendix C.

- Install the data collection and monitoring devices in the UH-1H helicopters at Ft. Rucker, Alabama.

- Monitor the data and provide data analysis and technical support during the tests at Ft. Rucker, Alabama.

- Study the feasibility of an on-board main rotor blade and tail rotor blade balance monitor system.

- Study the feasibility, with Avco Lycoming, of a simple engine performance monitor to automatically perform the HIT check testing required.

- Upon completion of the above two feasibility studies, design, fabricate and install the monitoring devices, and integrate them into the overall program.

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APPENDIX A

ADVANCED CHIP DETECTORS

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A-1.0 SYSTEM DESCRIPTION AND INSTALLATION

A-1.1 Tedeco Fuzz Discriminating Wear Debris Detection System

An E-1006 Tedeco laboratory power module and monitor panel and a B-475 Tedeco UH-1H main transmission chip detector were made available to BHT for evaluation (see Figures A-1, A-2, and A-3 and Table A-1).

The B-475 detector magnetically collects ferrous wear debris and generates a quantitative signal whose amplitude increases as the amount of wear debris accumulation at the sensor surface increases. The signal is displayed directly on a meter mounted in the E-1006 power module monitor panel. The signal generated by the detector is also differentiated. A large particle arriving at the sensor triggers a switching circuit and activates a chip light (Mode II) on the E-1006 monitor panel. Fuzz accumulation will be indicated on the meter but will not activate the warning light. The particle size sensitivity was set for a chip approximately .030 x .040 x .005 inch. A large amount of fuzz will decrease the switching circuit sensitivity so the detector should be cleaned when the fuzz accumulation meter indicates full scale.

The sensor was installed in the UH-1H AIDAPS transmission, replacing the standard chip detector. The power module was installed on the test stand console and used to monitor the transmission under test. The transmission was monitored with the THRESHOLD switch at position M, MODE switch at position II, and SEL switch at OPER. A temperature compensation circuit was installed in the particular model delivered and bypassed the calibration circuit and controls installed in the power module and monitor panel. The fuzz accumulation meter was read during each 30-minute test cycle and immediately after a Light II illumination. The sensor was removed and photographed after each Light II actuation.

A-1.2 BHT Capacitor Discharge Wear Discrimination System.

A capacitor is connected in parallel with the standard chip detector electrical contacts. When voltage is applied through the chip light, the capacitor becomes charged. As wear particles bridge the gap of the chip detector terminals, the capacitor discharges. A small sliver or fuzz is automatically burned off and the capacitor recharges. A large chip or a large, rapid collection of fuzz that does not burn off, discharges the capacitor and provides a short that turns on the chip light. The capacitor can also be connected in series with a switch so that when the chip light is activated the capacitor is not discharged automatically but manually by depressing the switch.

The Capacitor Discharge Chip Detector Control Box (Figure A-4) was installed and replaced the 42-degree gearbox chip detector light. The system was operated in the manual mode until the first chip indication light was observed. In the event the chip light

did not extinguish after switching to automatic, the system was returned to the manual mode and six attempts were made to extinguish the chip light by pushing the manual burnoff push button. Test log entries were made at each chip light indication and pictures taken of the chip detector.

A-1.3 BHT Current Pulse Wear Discrimination System.

A current pulse control box is connected to a standard chip detector. When the chip light is activated by fuzz or chips, the control unit will, when manually actuated by a push button, direct a controlled current pulse through the chip detector. A small sliver or fuzz will burn-off, turning off the chip indication light. A chip or a large rapid collection of fuzz will not burn off and the chip indication will remain on.

The Current Pulse Wear Particle Discriminator Control Unit (Figure A-5) was installed in conjunction with the 90-degree gearbox chip detector light. The amount of current and pulse width is variable and was initially set at 3/4 maximum setting. When a chip was indicated, up to six attempts were made to extinguish the chip light by actuating the pulse button. In the event the chip light did not extinguish, the current and time settings were increased to maximum and the pulse button actuated again as above. Test log entries were made at each chip light indication and pictures taken of the chip detector.

A-2.0 FIRE HAZARD DETERMINATION

A test to simulate transmission operating conditions was set up in the BHT Chemistry Laboratory to determine if a fire hazard existed while operating the BHT burn-off chip detectors. The tests were conducted with both MIL-L-7808 and MIL-L-23699 oils and up to 330°F (which is 100°F above the maximum allowable bulk oil temperature). The test was set up as illustrated in Figure A-6. The chip detector was supported by an adjustable stand and was positioned at various levels with respect to the oil level, from submerged to six inches above. The agitator was run at a speed sufficient to achieve surface splashing of the oil. Capacitors of 94 micro-farads were installed across the chip detector terminals, charged to 28 volts and remotely fired. Steel slivers used in the test were of fine steel wool of approximately .001 x .001 cross section. The tests indicated that as tested, no fire hazard exists as a result of a particle being burned off.

A-3.0 RESULTS

The advanced chip detector systems were installed during the first two test blocks of the Removal Limit Confidence Test described in the body of this report. Spalled bearings and scored gears installed in the main transmission and gearboxes provided a source of debris.

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Fuzz build-up was registered on the Tedeco debris accumulation meter. Large spall flakes activated the Mode II Light on eight different occasions with a concurrent large increase indicated on the debris accumulation meter. The test results are presented in Figure A-7 through A-12. The cable connecting the Tedeco sensor and control box was damaged during the first transmission teardown and was inoperative for the first 24.2 hours of the next test sequence. After repair, fuzz build-up was registered on the debris accumulation meter. Large spall flakes activated the Mode II Light on two different occasions with a concurrent large increase indicated on the debris accumulation meter. The test results are presented in Figures A-13 through A-15. The connector on the sensor unit was damaged during the second transmission teardown and caused a short in the temperature compensating (calibration) circuit. No further Tedeco data was collected.

A large amount of fuzz was rapidly accumulated on the 90-degree gearbox chip detector. The current pulse system failed to burn off the fuzz (Figure A-16). The capacitive discharge system was then installed with similar results (Figure A-17). The inability of the systems to burn off the debris was traced to the rapid rate of collection of debris fuzz from the damaged 90-degree gearbox gears. This collection was much more rapid then would be experienced in an operational gearbox.

In a parallel test program, a manually activated capacitive discharge chip detector system was installed on the flight test YAH-63 helicopters. A precautionary landing would be performed only if the chip light was actuated and could not be extinguished by the manually activated burn-off system. A post flight inspection of the chip detector was conducted any time the system was activated. Preliminary results from the program have been received. During the first 50 actuations, the chip light was extinguished 45 times with no further investigation indicated during the post-flight inspection of the detector. The chip light was not extinguished five times and a precautionary landing was performed. Post flight inspection of the detector indicated that a transmission inspection was warranted.

A-4.0 CONCLUSIONS

The Tedeco discriminating system operated satisfactorily as tested, indicating debris fuzz without actuating a chip indication until a large particle was captured.

The BHT burn-off systems, as tested in the BHT transmission test lab, did not burn-off any fuzz, but demonstrated that a rapid rate of fuzz that is indicative of gear scoring could be accumulated rapidly and indicate the fault. The preliminary results of the BHT capacitive discharge system, as installed and tested in the YAH-63 flight test program, indicate the system operates satisfactorily.

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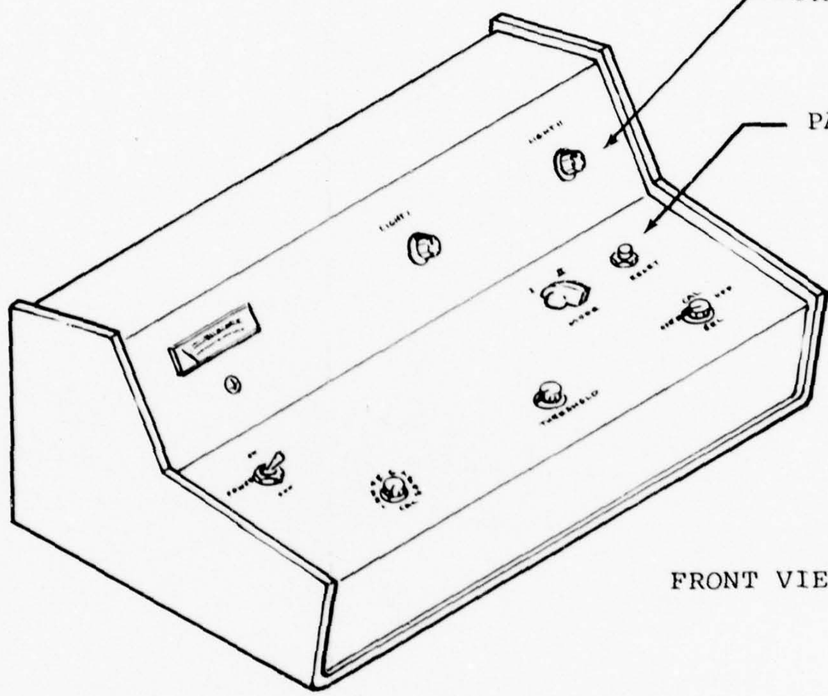
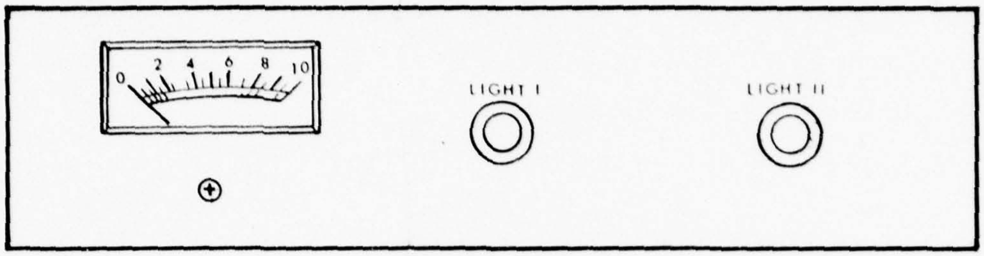
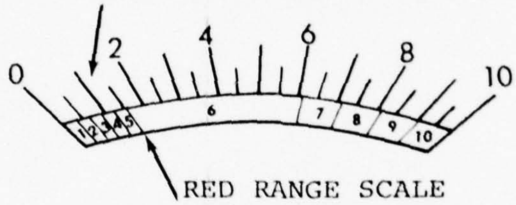


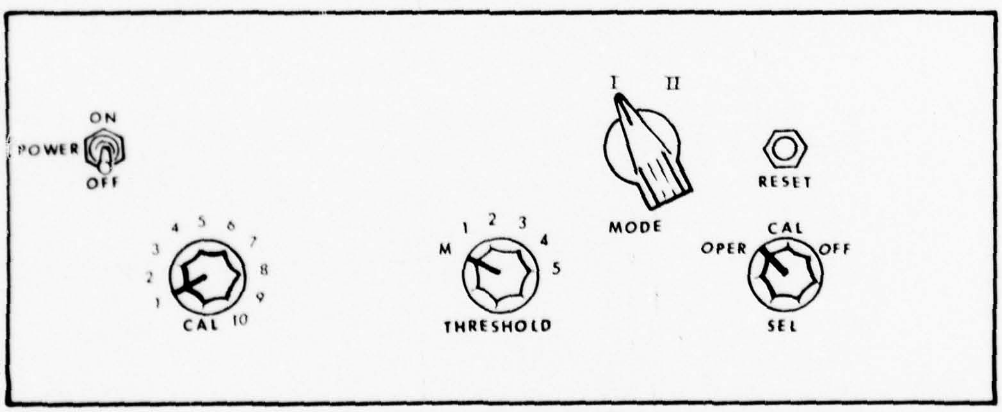
Figure A-1. TEDECO monitor control box.



PANEL "A"



ENLARGED VIEW OF SCALE



PANEL "B"

Figure A-2. TEDECO monitor box panel configuration.

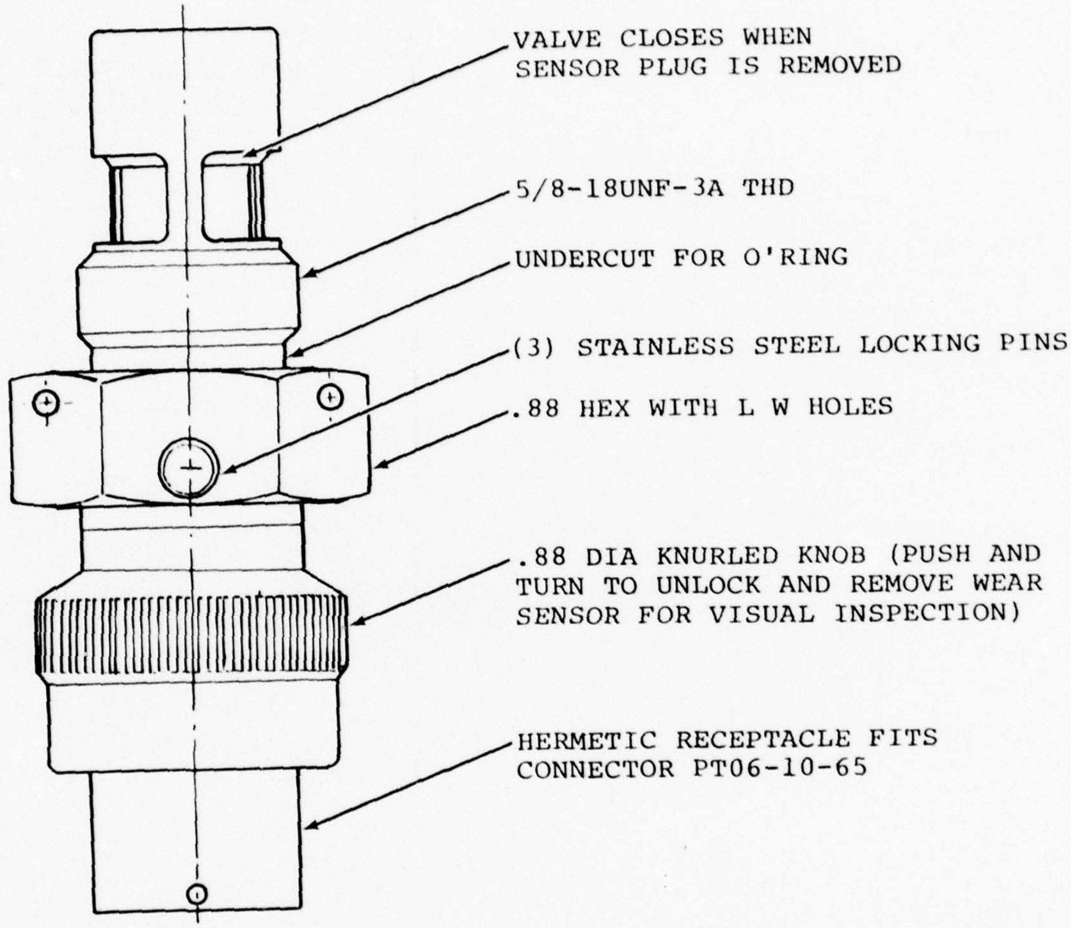


Figure A-3. TEDECO B475 chip detector.

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TABLE A-I

TEDECO CHIP DETECTOR MONITOR

OPERATING INSTRUCTIONS

1. Set "POWER" switch to on position.
2. Press "RESET" button.

CALIBRATIONS

(a) Turn selector (SEL) switch to calibrate (CAL) position.

(b) Note reading on red range scale.

(c) Turn calibration (CAL) switch to number corresponding to reading obtained by instructions in note (b).

METER INDICATION

(Total accumulated wear debris)

(a) Turn selector switch to operate "OPER" position.

(b) Turn threshold switch to position "M".

MODES

Mode I - "Anti-Panic Readout"

(a) Set "MODE" switch to position "I".

(b) Turn threshold switch to position "I".

(c) Debris accumulation at sensor will trigger "LIGHT I".

(d) Turn threshold switch to position "2"; light will go out until it is again triggered by further accumulation.

(e) This cycle may be repeated up to threshold position "5".

(f) The interval between successive indications permits estimate of rate of failure progression.

Mode II - "Small Particle Discrimination"

(a) Set "MODE" switch to position "II".

(b) Large particles, when arriving at sensor location, will trigger "LIGHT II"; fuzz or small particles (even quantities larger than single large particle) are disregarded.

(c) When indication is obtained, system can be reset to receptive status by pressing "RESET" button.

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TABLE A-I (Cont'd)

TEDECO CHIP DETECTOR MONITOR

OPERATING INSTRUCTIONS

(d) Next arriving large particle will trigger light again.

(e) Cycle may be repeated until sensor saturates.

NOTES:

(1) When switching from "MODE I" to "MODE II", press "RESET" button to return system to receptive status.

(2) When switching from "MODE II" to "MODE I", large particle indication is lost.

(3) Unit may be used in conjunction with "TEDECO QUANTITATIVE MAGNETIC WEAR SENSORS".

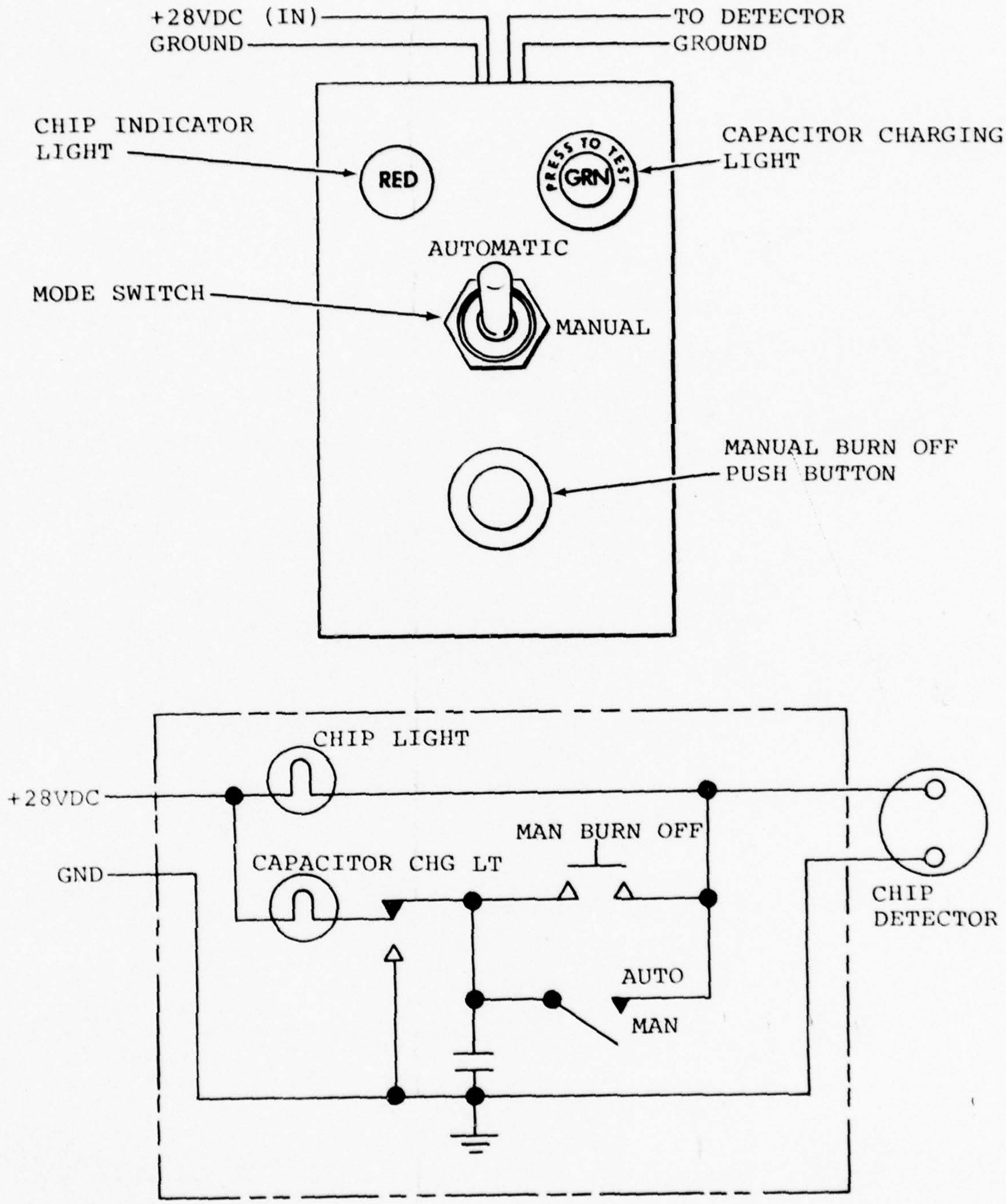

Figure A-4. Capacitor discharge chip detector control box schematic.

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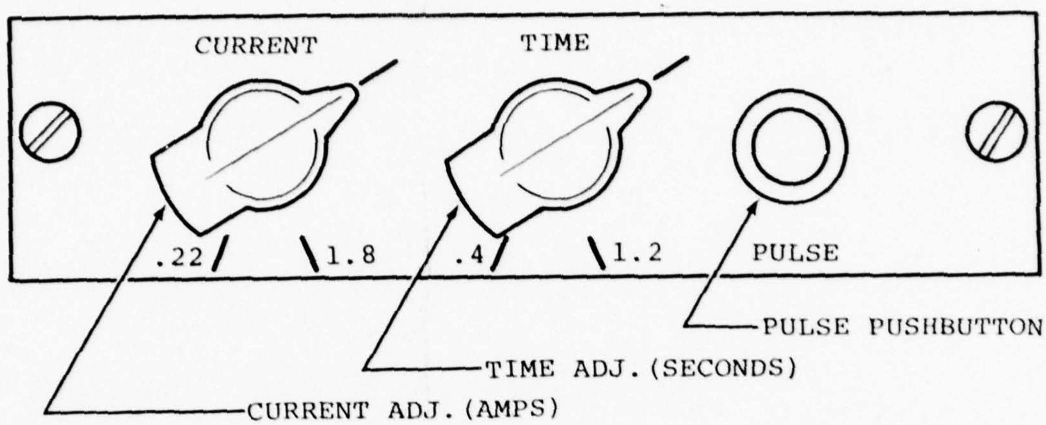

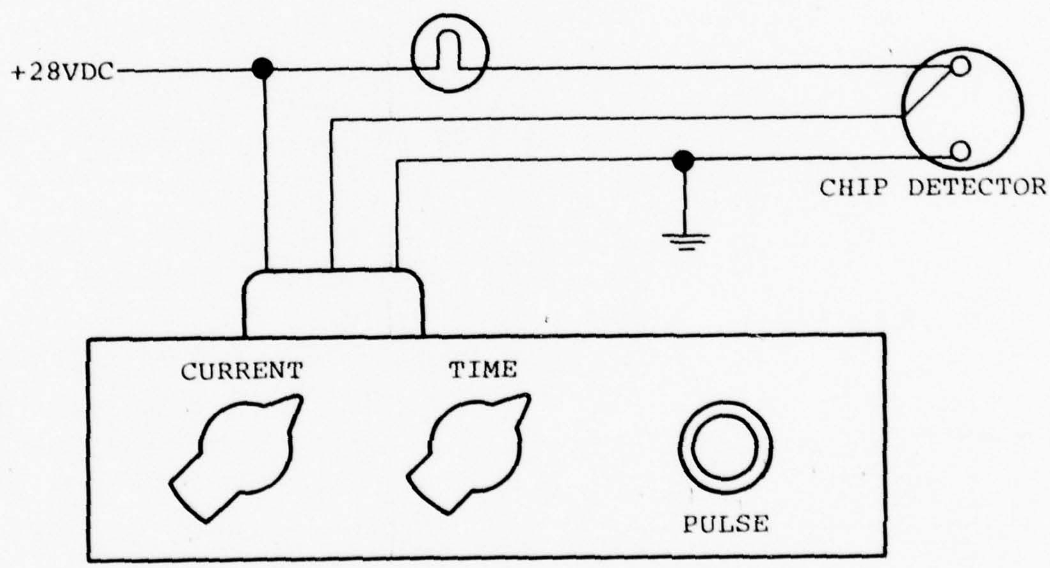

Figure A-5. Current pulse control unit.

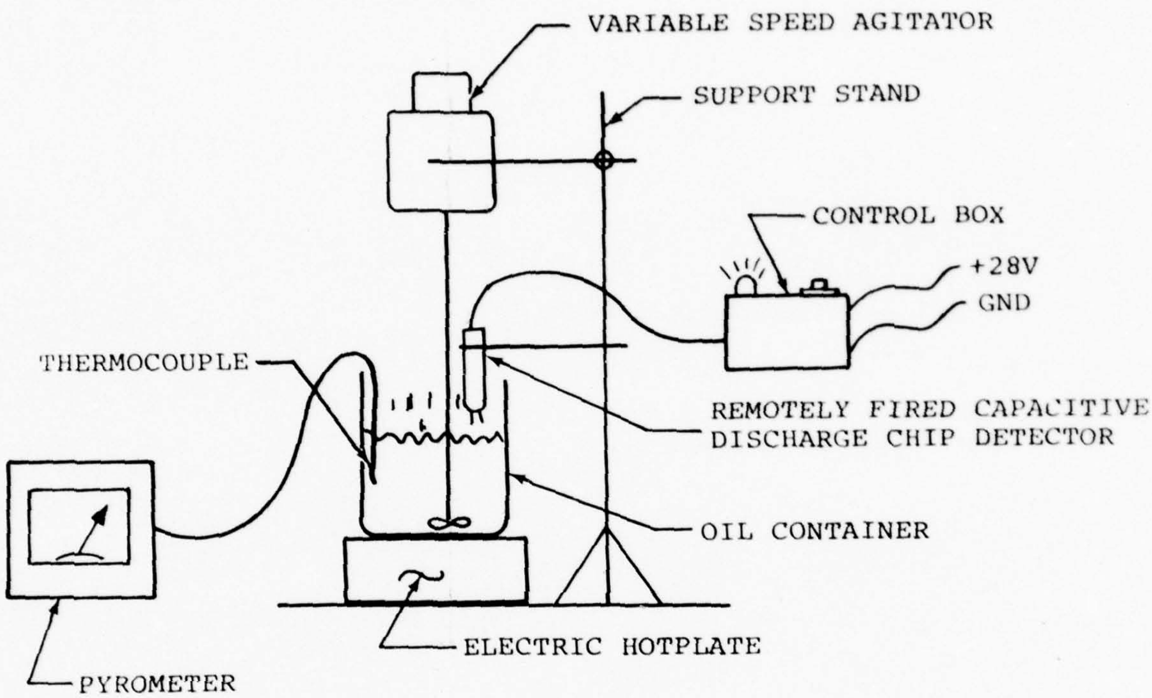

Figure A-6. Fire hazard test schematic.

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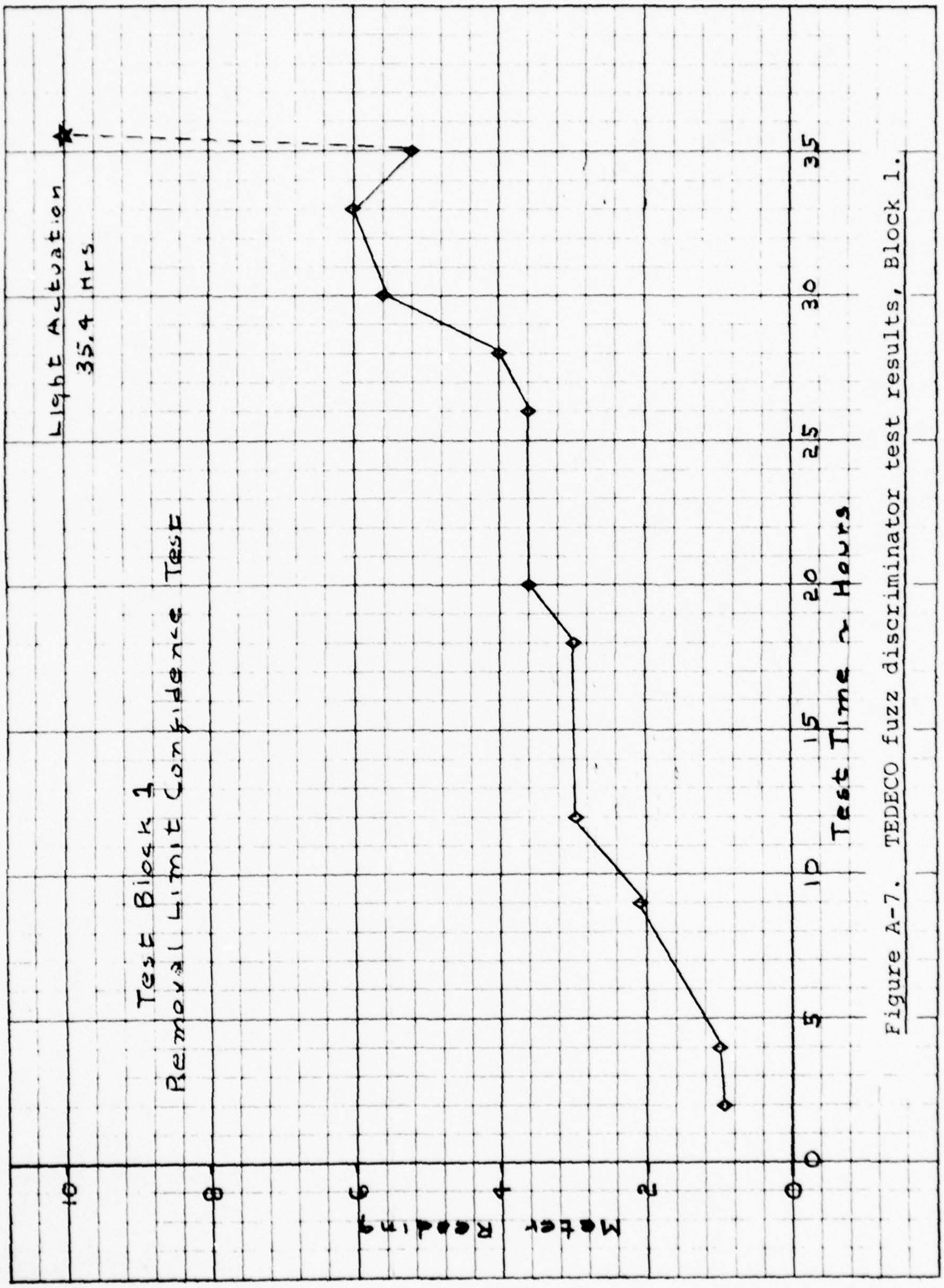

Figure A-7. TEDECO fuzz discriminator test results, Block 1.

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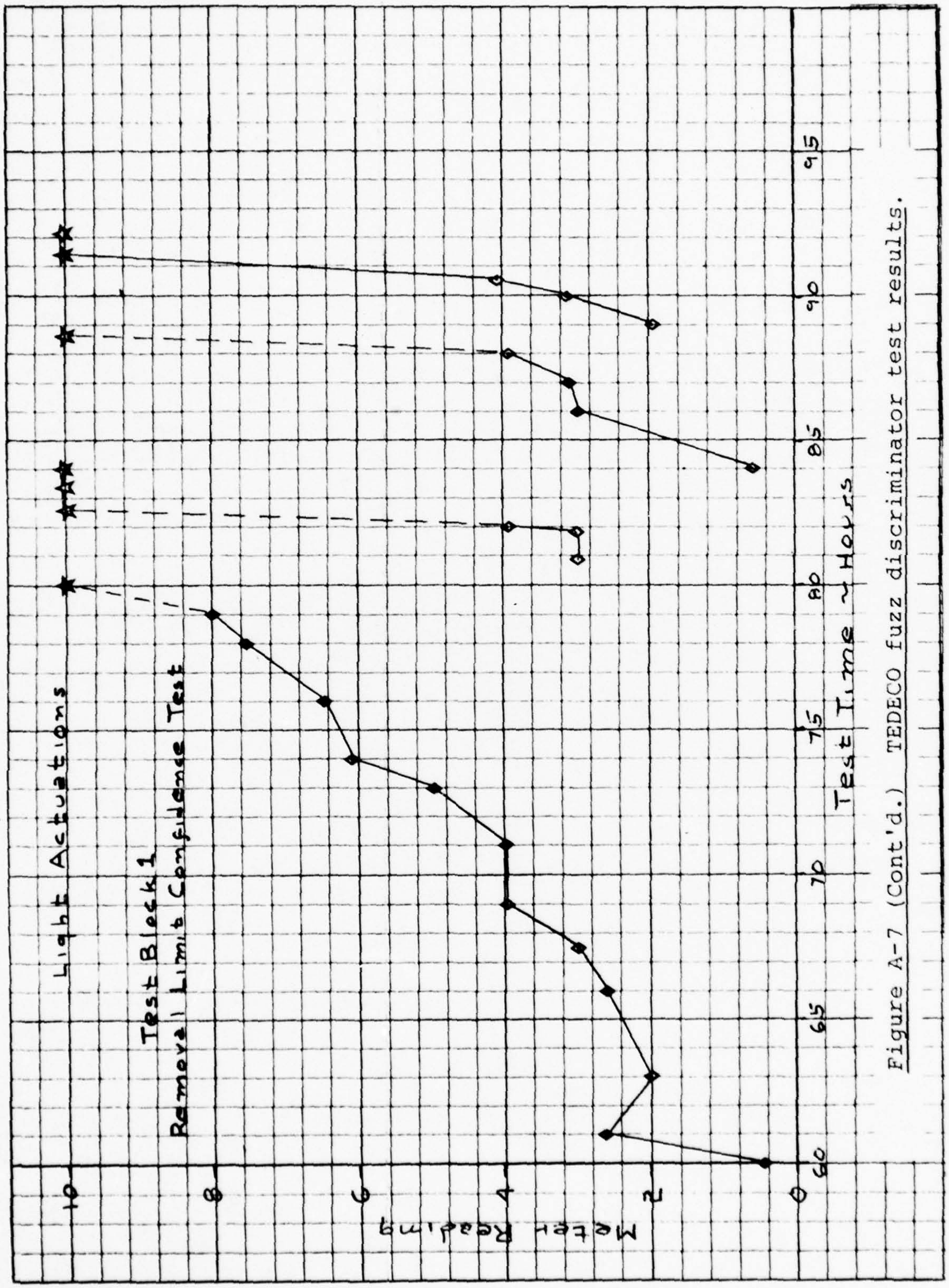

Figure A-7 (Cont'd.) TEDECO fuzz discriminator test results.

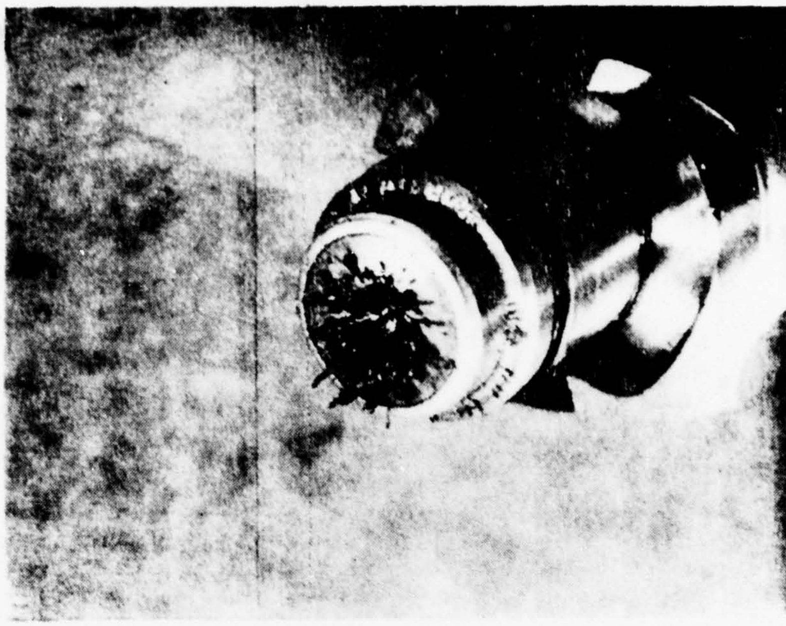

Figure A-8. TEDECO detector at 35.4 hours, Block 1.

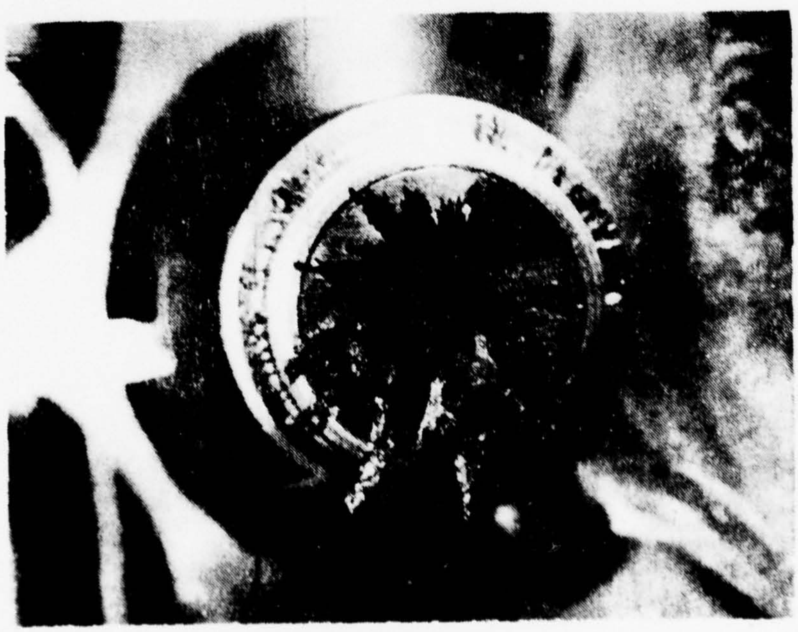

Figure A-9. TEDECO detector at 80.0 hours, Block 1.

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Figure A-10. TEDECO detector at 88.5 hours, Block 1.

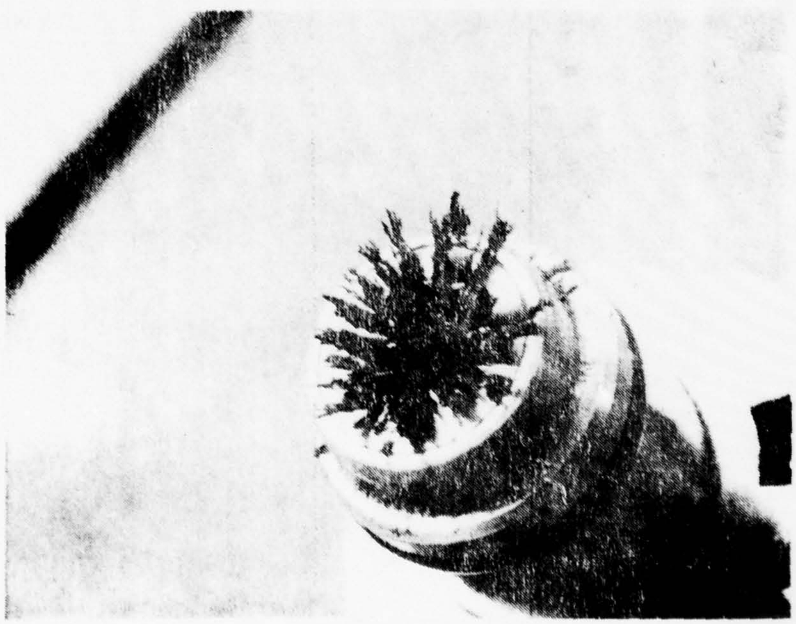

Figure A-11. TEDECO detector at 91.3 hours, Block 1.

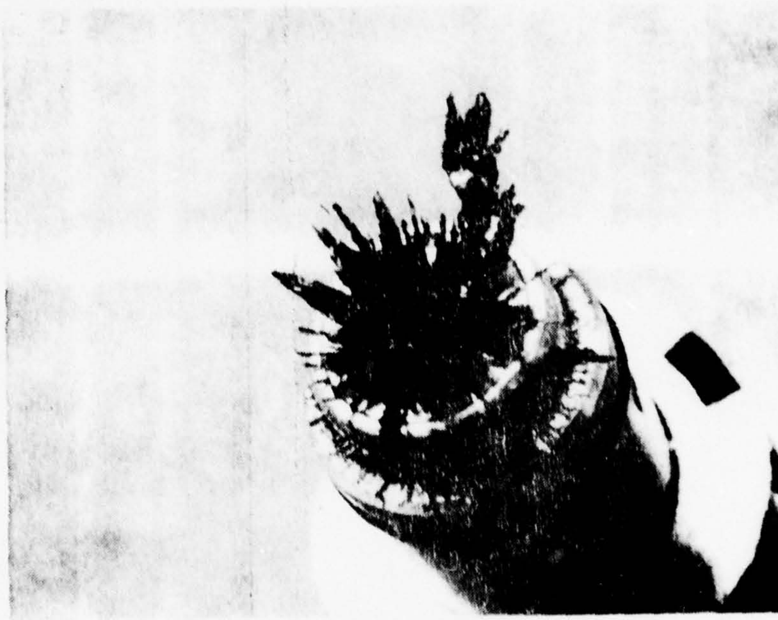

Figure A-12. TEDECO detector at 91.8 hours, Block 1.

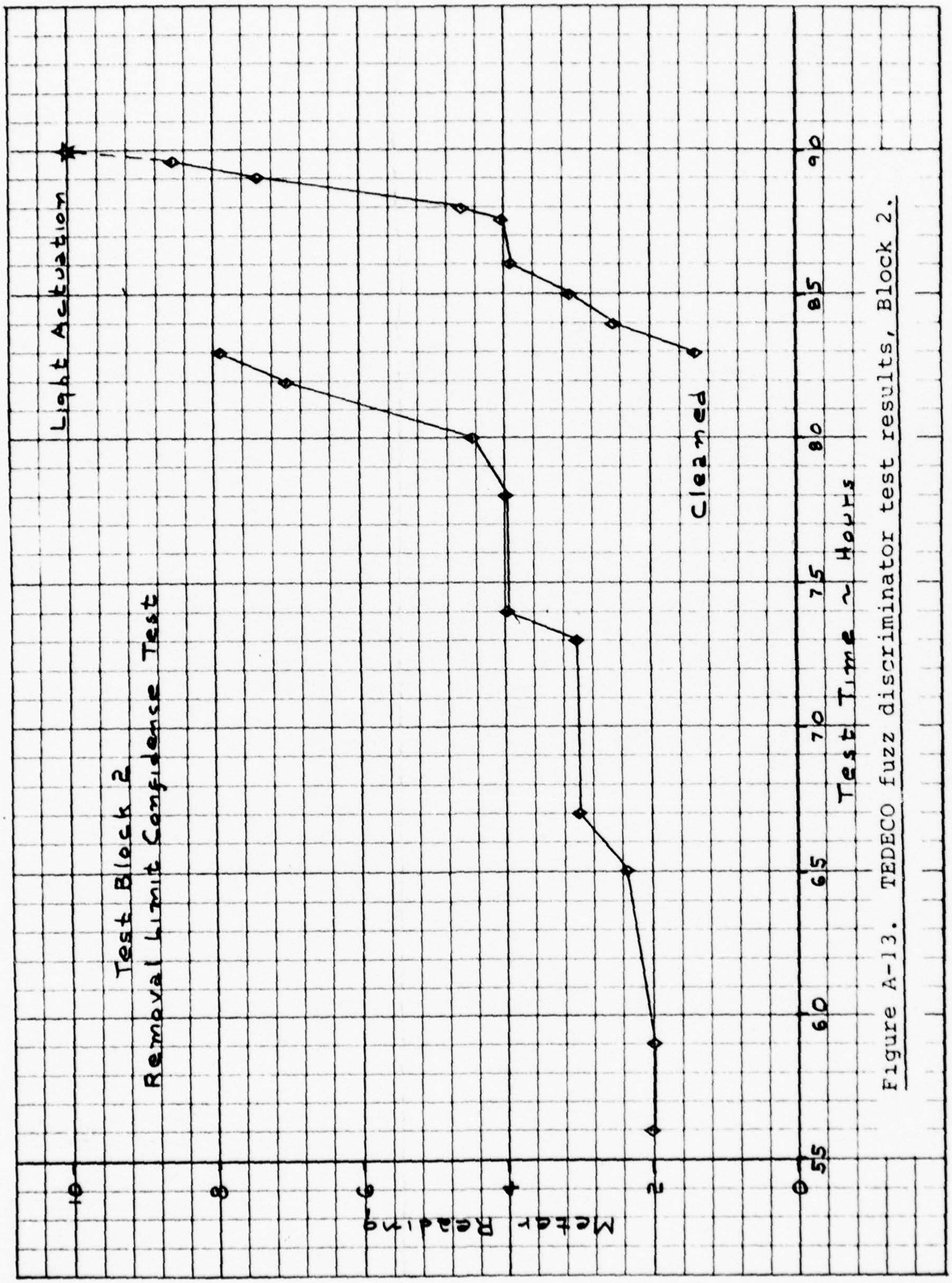

Figure A-13. TEDECO fuzz discriminator test results, Block 2.

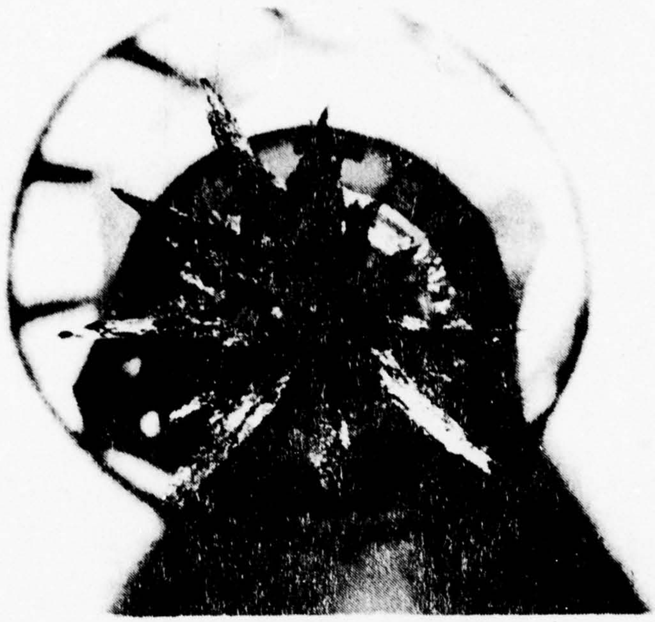

Figure A-14. TEDECO detector at 90.0 hours, Block 2.

Figure A-15. TEDECO detector at 90.1 hours, Block 2.

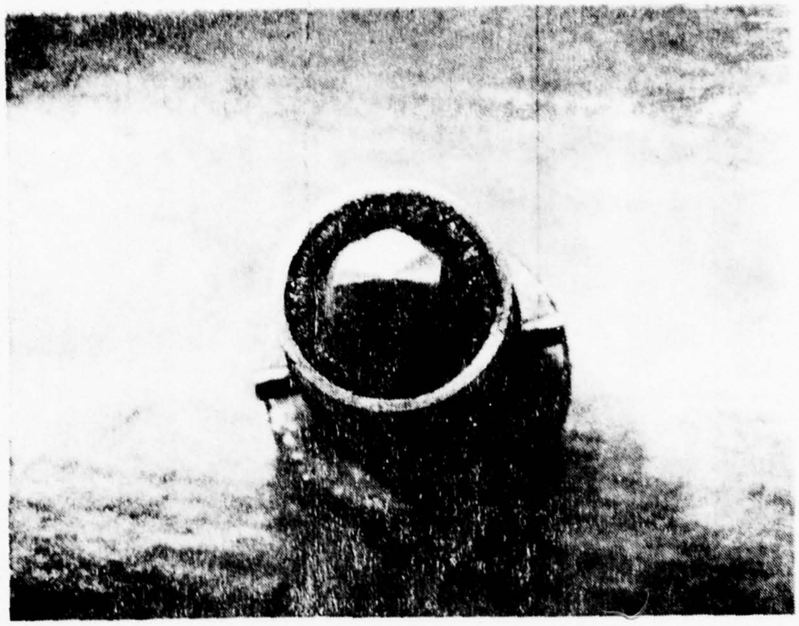

Figure A-16. 90-degree gearbox chip detector; current pulse discharge system.

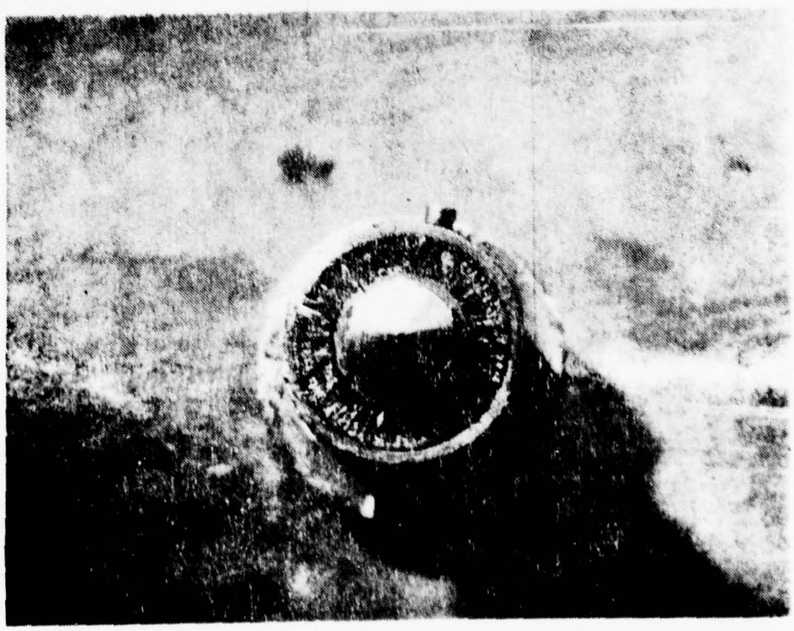

Figure A-17. 90-degree gearbox chip detector; capacitive discharge system.

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APPENDIX B

BEARING AND GEAR FAULT DETECTION

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B-1.0 BEARING DEFECT VIBRATION MONITORING PROGRAM

B-1.1 Discussion

The BHT bearing defect detection analysis is similar to the MTI technique reported in the body of this report. When a defect in the inner or outer race of a bearing is struck by a rolling element, a number of structural resonances are excited. A defect on the rolling element has the same effect. The particular rolling element pass frequency, related to the location of the defect, amplitude modulates the structural resonances. By demodulating one of these resonances, a rolling element pass signal is recovered. The frequency of the signal is then compared with the calculated frequency that determines which particular bearing is defective.

A block diagram illustrating the flow of information in the BHT bearing detection system is outlined in Figure B-1. The accelerometer signal in the frequency range of 0-80 kHz is conditioned by a variable band-pass filter of approximately 2 kHz bandwidth. The output signal of the band-pass filter is provided to the detector circuit consisting of a half-wave rectifier and low-pass (1 kHz) filter. This circuit demodulates and frequency limits the vibration signal. The demodulated signal is then spectrum analyzed. A significant spectrum peak at the fundamental frequency of the bearing defect indicates that a fault has been detected. The scope and x-y plotter are used to monitor and capture the data signals.

An automatic monitor, illustrated in Figure B-2, was developed to replace the spectrum analyzer. The demodulated signal from the low-pass filter of Figure B-1 is peak and average detected and the peak and average values are then compared in the comparator. The defect threshold ratio established in the comparator will not be exceeded for a no-defect condition and there is no more action required in the monitor circuit. The threshold ratio in the comparator will be exceeded if the input signal is from a defective component. The comparator then enables the counter which starts counting clock pulses at the frequency of the incoming signal and starts the reset timing. When a defect is present the pulse of the incoming signal is continually counted until the count reaches the level of the logic gate and energizes the fault indicator. When noise or random signals exceed the comparator the counter is enabled but is reset by the timer before a fault is indicated. The monitor must receive a set number of counts from the incoming signal within a set time frame before a fault is indicated. The input signal to the monitor and the resultant comparator signal for a no-defect condition and for an implanted bearing fault condition are presented in Figure B-3.

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B-1.2 Results

The data presented was retrieved from the data tapes generated during the second test block of the Removal Limit Confidence Test. Seventeen bearings with twenty documented defects were installed in the UH-1H transmission and gearboxes. The implant bearings, defects, installed location and anticipated defect frequencies are listed in Table B-I.

Spectral analyses of the amplitude demodulated vibration sensor signals with the implanted bearings of Table B-I were obtained and are presented in Figures B-4 to B-14. All the vibration signal data exhibited a spectral line within $\pm$ 5% of the center calculated frequency with a minimum amplitude level of 6 dB above the noise level.

Spectral analyses of the frequency demodulated vibration signals plotted of non-defective transmissions and gearboxes were also obtained. These results are presented in Figures B-4A through B-14A. The spectral plot of implant bearing MAIC-016 is not presented because comparable no-defect data is not available. Table B-I summarizes the detected defects and detection frequencies.

Thirteen Category "B" defects (Table B-II) were indicated by the defect monitor analysis which had not been documented. Ten of the defects were verified by teardown inspection. The bearings with the three defects not validated were defective in other areas and it is presumed that debris from the defective bearing caused the defect indication. In no case was a non-defective bearing identified as defective.

Accelerometer locations were critical on the 90-degree box. The initial accelerometer mounting configuration did not transmit adequate vibration energy to the installed B&K accelerometers to provide a defect signal. The B&K accelerometers were removed from the mounting brackets and cemented on the input and output quill case. This relocation provided sufficient signal strength to isolate the input and output bearing faults. Either accelerometer located at the input or output quill of the 42-degree gearbox would indicate both the input or output quill bearing faults. No location optimization was experimented with on the main transmission.

Although numerous resonant frequencies were detected across the 60 kHz bandwidth, the band-pass frequencies noted in Table B-II exhibited the most pronounced spectral data for fault detection of the noted implants. In general, the higher frequency band passes produced better signal-to-noise ratios than the lower frequency band-passes. Three band-pass frequencies (1-3 kHz, 20-24 kHz, 50-55 kHz) produced amplitude detection large enough to establish that a defect was present in all the bearing defects

tested. Theory predicts that the natural frequency of the inner and outer races would be the two discrete carrier frequencies for each bearing. Fortunately this is not the case, and apparently the rolling element defect passage excites numerous structural resonances that carry the defect signal. Some of the spectra cannot be readily identified, but are academic considerations at present and do not interfere with the detection analysis process.

The monitor circuit was developed using the output signal of the B&K vibration transducer from the 42-degree gearbox input quill. The monitor circuit operated satisfactorily with a peak to average ratio of 10.3 set into the comparator and ten clock pulses in 100 milliseconds set in the logic gate before the fault detector was energized. The monitor design is susceptible to steady-state one-per-revolution and gear frequencies that possibly can fall into the band of frequencies monitored. If this is the case in other installations these steady-state frequencies will have to be filtered out. High noise levels inherent in power changes can start the counter in the monitor circuit and possibly trip the fault indicator.

The spectral level amplitude generated from a Category "B" Fault was not consistently distinguishable from a Category "D" Fault; therefore, present indications are that the magnitude of a detected defect cannot be determined by the amplitude of the spectral signal. The testing conducted has indicated that a fault is truly present, however, when the spectral frequencies are present.

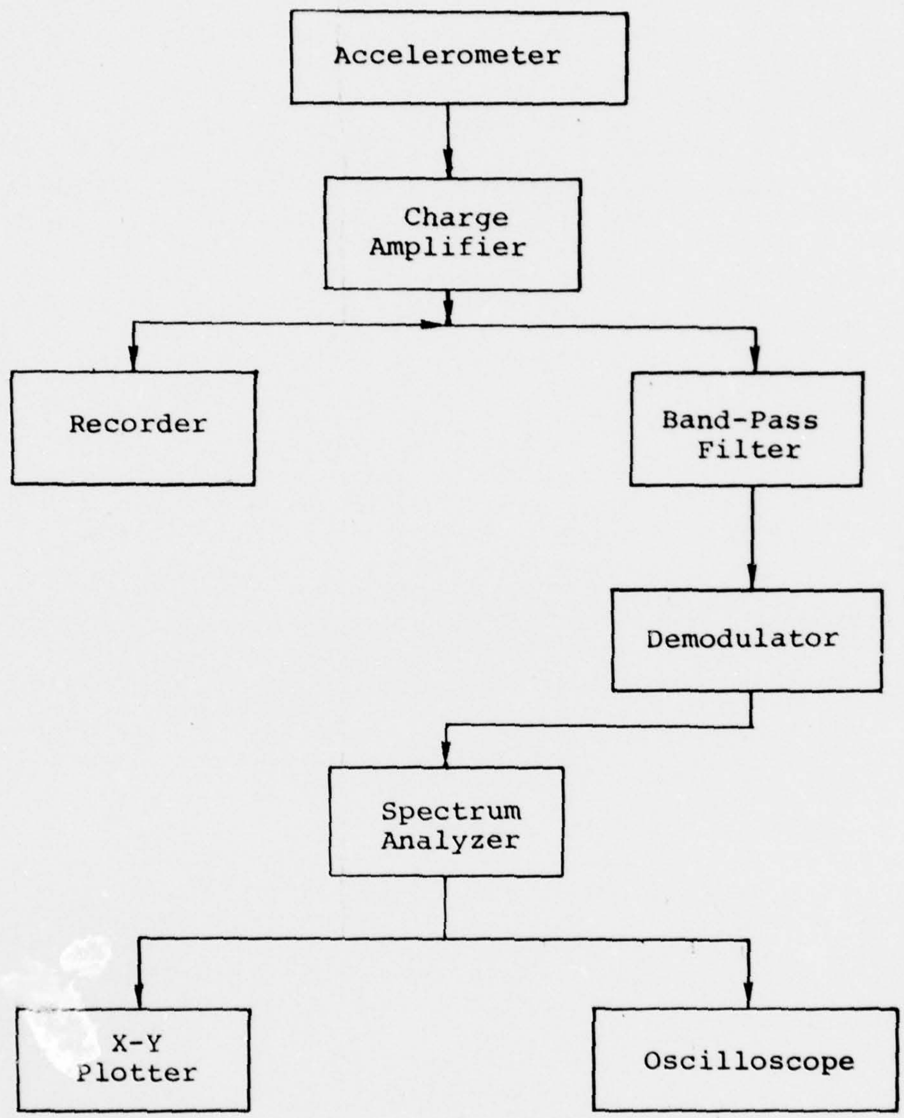


Figure B-1. Bearing defect detection block diagram.

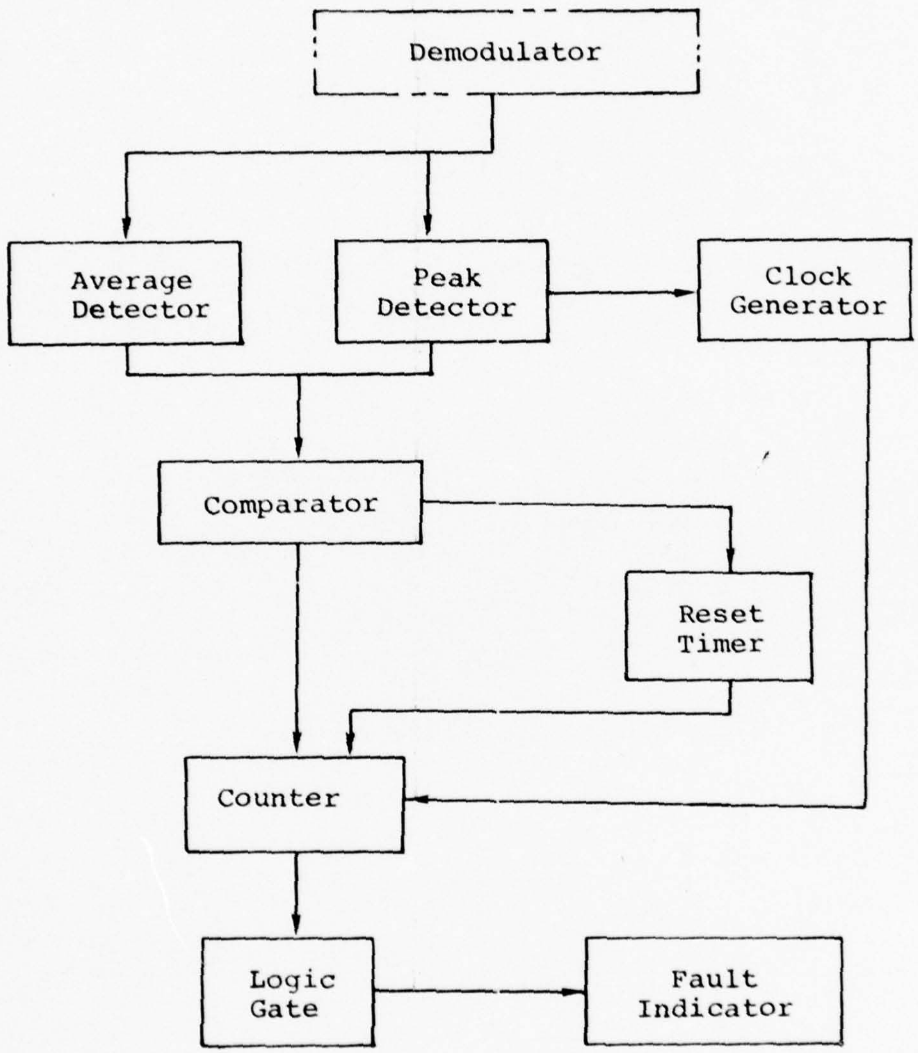
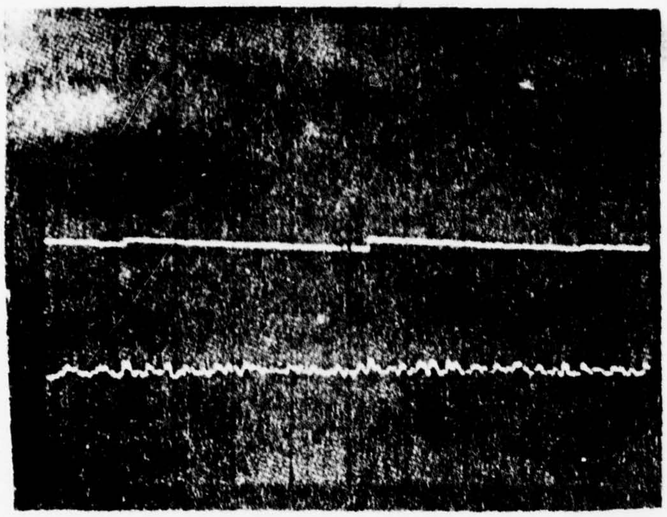
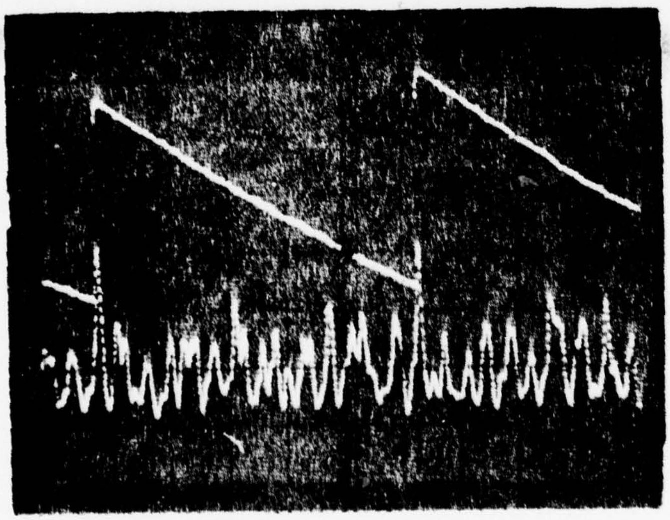


Figure B-2. Bearing defect monitor block diagram.



Monitor operation; no defect.



Monitor operation; implanted defects.

Figure B-3. Comparator monitor operation.

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TABLE B-I

DOCUMENTED BEARING IMPLANT DETECTION

P/N & Component	Location	P/N Implant	Degradation & Category	Track Tape	Band Pass Freq (kHz)	*Defect Freq (Hz)
42° Gearbox						
-143 Ball	Input	MAIC-010	"D" Ball	6	19 - 20	330 fb
	Output	MAIC-011	"C" Inner Race	7	19 - 21	504 fi
-310 Roller	Input	MAIC-021	"D" Inner Race	7	19 - 20	594 fi
	Output	MAIC-009	"D" Inner Race	6	19 - 20	594 fi
90° Gearbox						
-143 Ball	Input	MAIC-012	"D" Inner Race	8	14 - 16	504 fi
-424 Ball	Output	MAIC-016	"D" Outer Race	9	1 - 3	204 fo
406 Roller	Input	MAIC-019	"D" Inner Race	8	16 - 16	593 fi
			"D" Outer Race	8	14 - 16	410 fo
			"D" Roller	8	1 - 3	382 fb
-407 Roller	Output	MAIC-020	"D" Outer Race	9	31 - 33	241 fo
			"D" Roller	9	31 - 33	220 fb

(*) fi = Frequency associated with inner race defect @6600 RPM engine speed.

fo = Frequency associated with outer race defect @6600 RPM engine speed.

fb = Frequency associated with roller or ball defect @6600 RPM engine speed.

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TABLE B-I (Cont'd)

DOCUMENTED BEARING IMPLANT DETECTION

P/N & Component	Location	P/N Implant	Degradation & Category	Track Tape	Band Pass Freq (kHz)	Defect Freq (Hz)
XMSN						
-136 Ball	Mast	BHC-124	"D" Outer Race	2	15 - 17	47 fo
-143 Ball	T/R Quill	MAIC-013	"D" Inner Race	3	28 - 30	504 fi
	Offset Quill	MAIC-014	"D" Inner Race	5	22 - 24	485 fi
	Sump Quill	MAIC-015	"D" Inner Race	5	22 - 24	485 fi
-245 Ball	Xmsn Quill	MAIC-017	"D" Inner Race	3	28 - 30	732 fi
-246 Ball	Input	MAIC-018	"C" Inner Race	3	9 - 11	960 fi
-310 Roller	T/R Quill	MAIC-008	"D" Roller	5	46 - 47	376 fb
	Sump Quill	MAIC-007	"C" Outer Race	3	2 - 4	397 fo
-725 Roller	Lower Planet	BHC-071	"D" Roller	3	28 - 30	321 fb

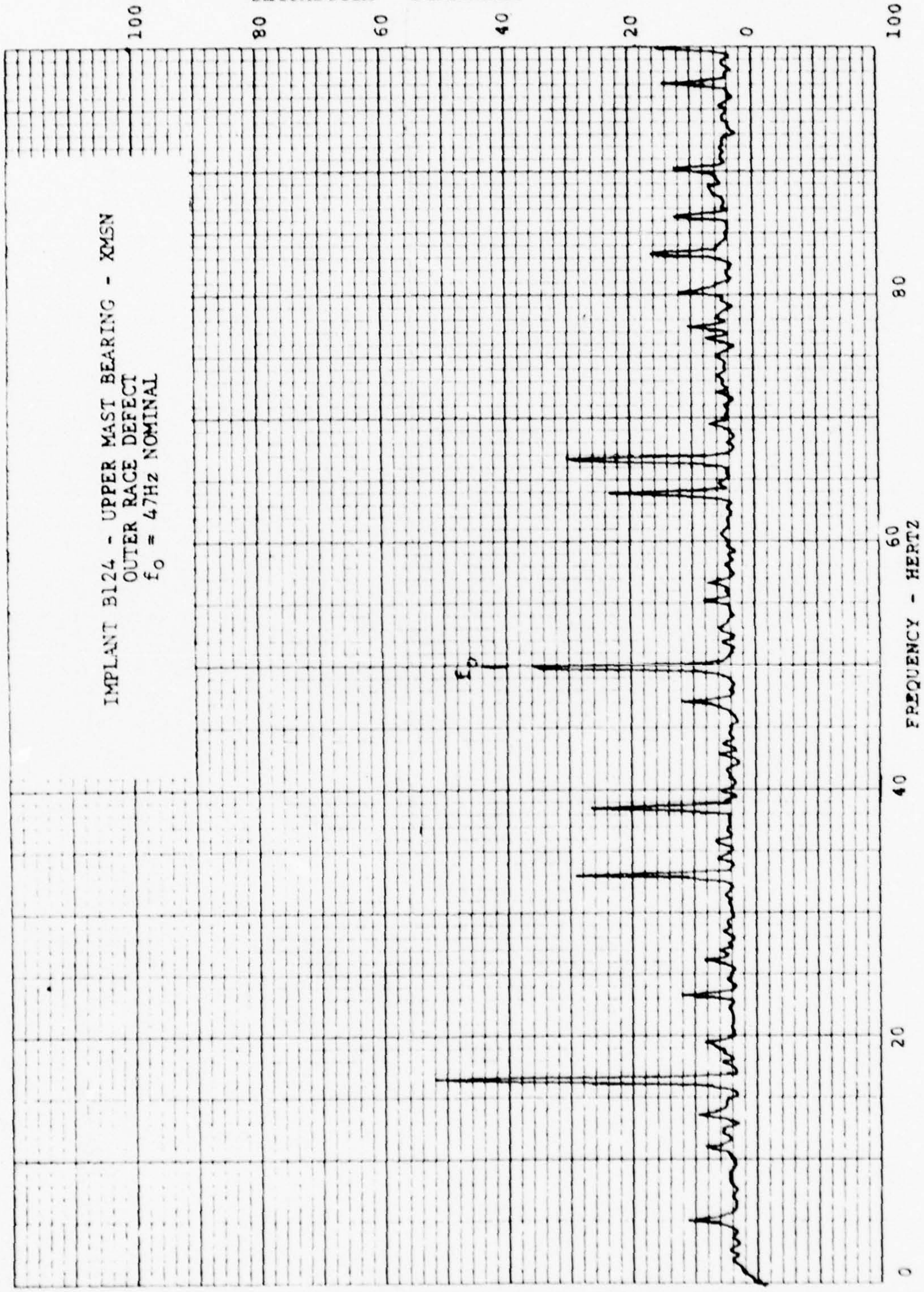

Figure B-4. Demodulated signal spectrum - mast bearing defect.

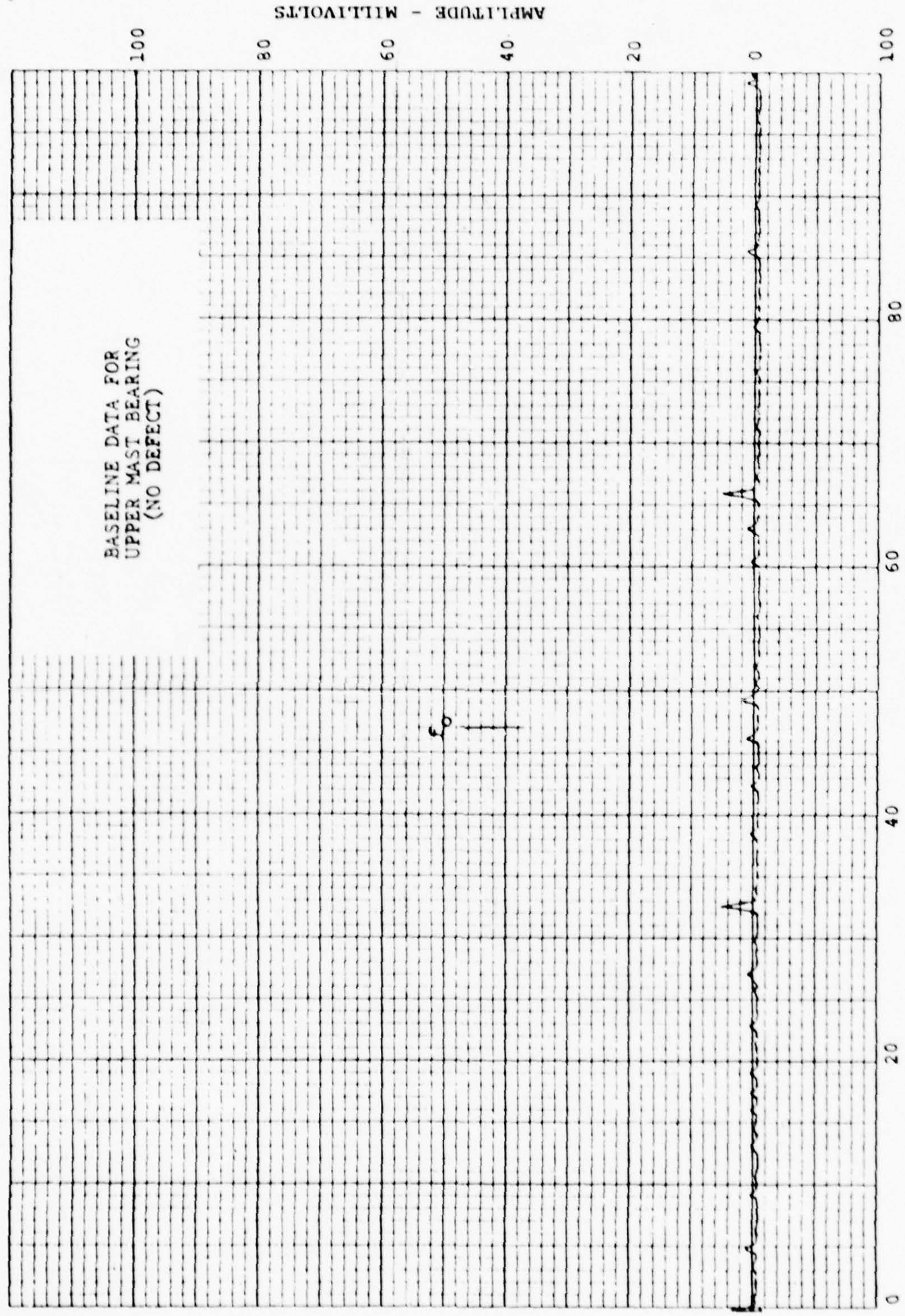

Figure B-4A. Demodulated signal spectrum - no mast bearing defect.

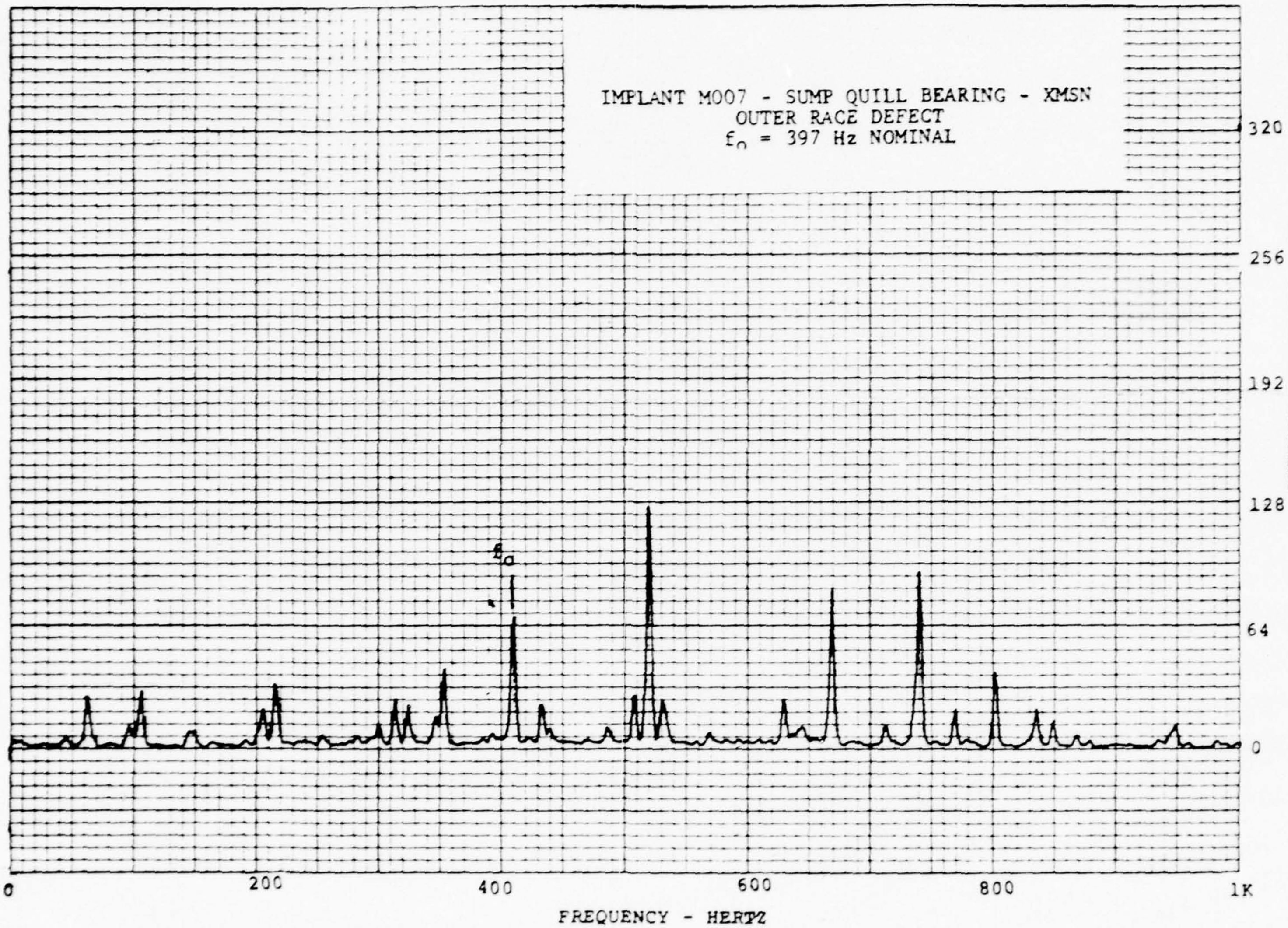

Figure B-5. Demodulated signal spectrum - transmission sump quill bearing defect.

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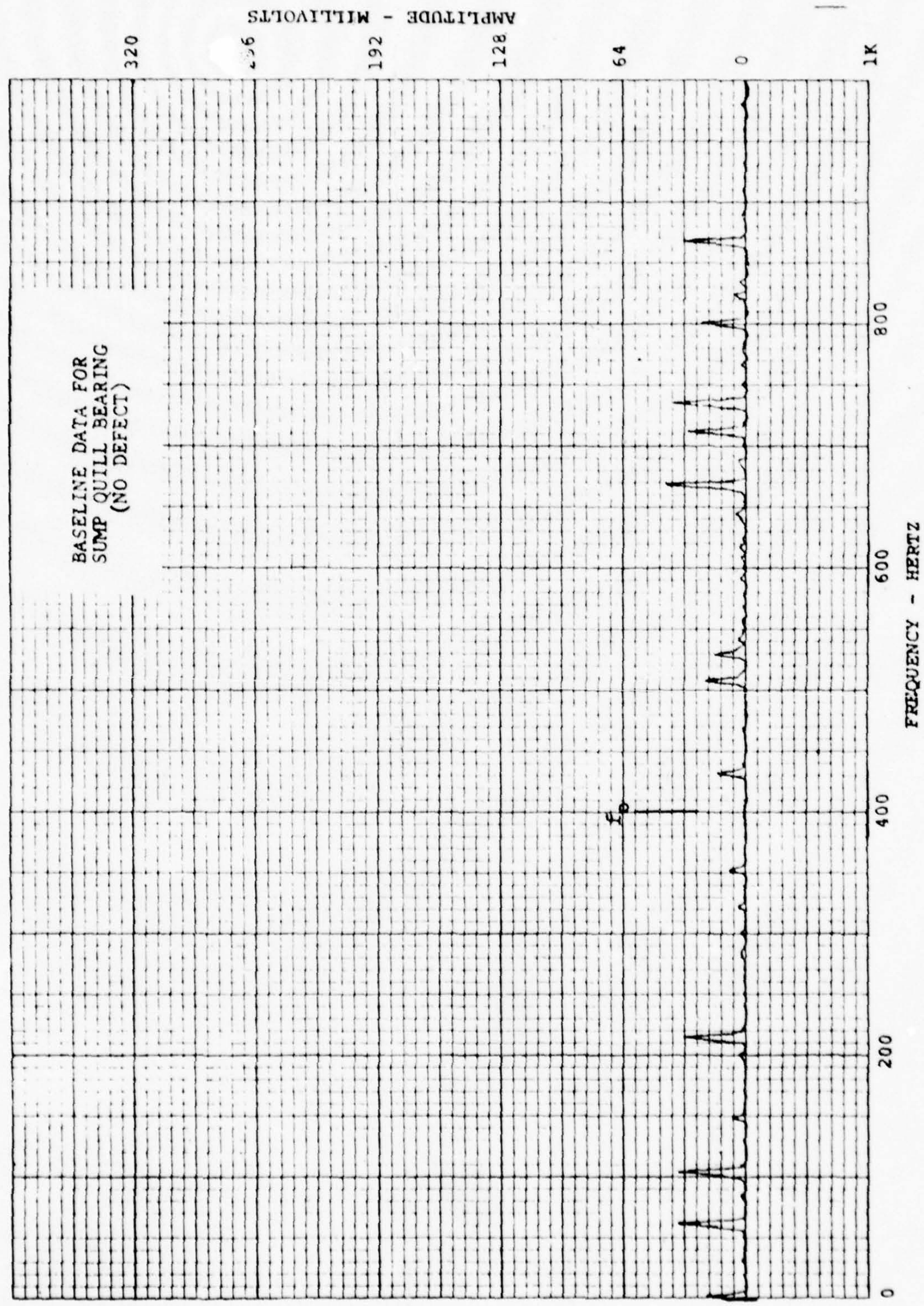

Figure B-5A. Demodulated signal spectrum - no transmission sump quill bearing defect.

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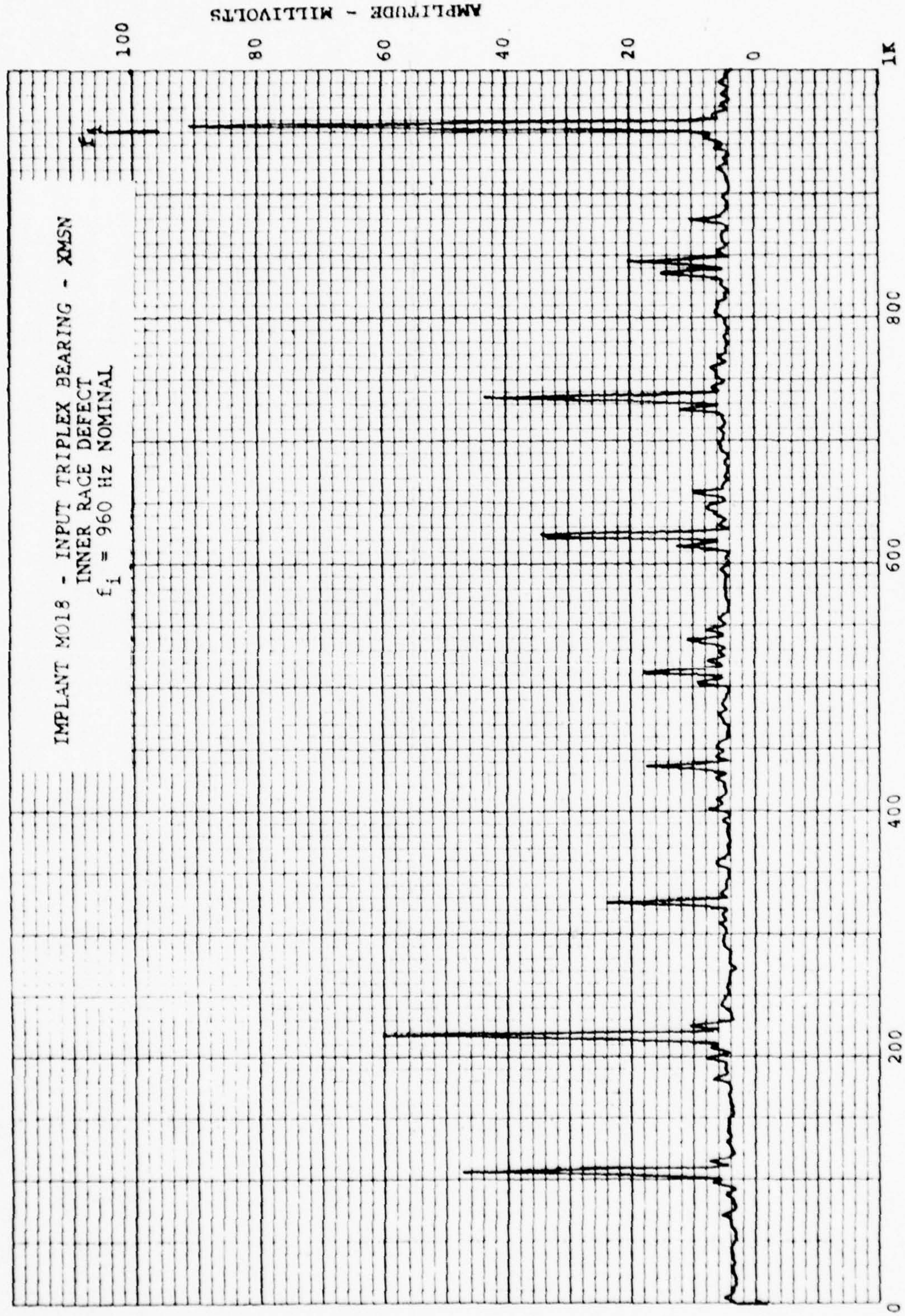

Figure B-6. Demodulated signal spectrum - transmission input bearing defect.

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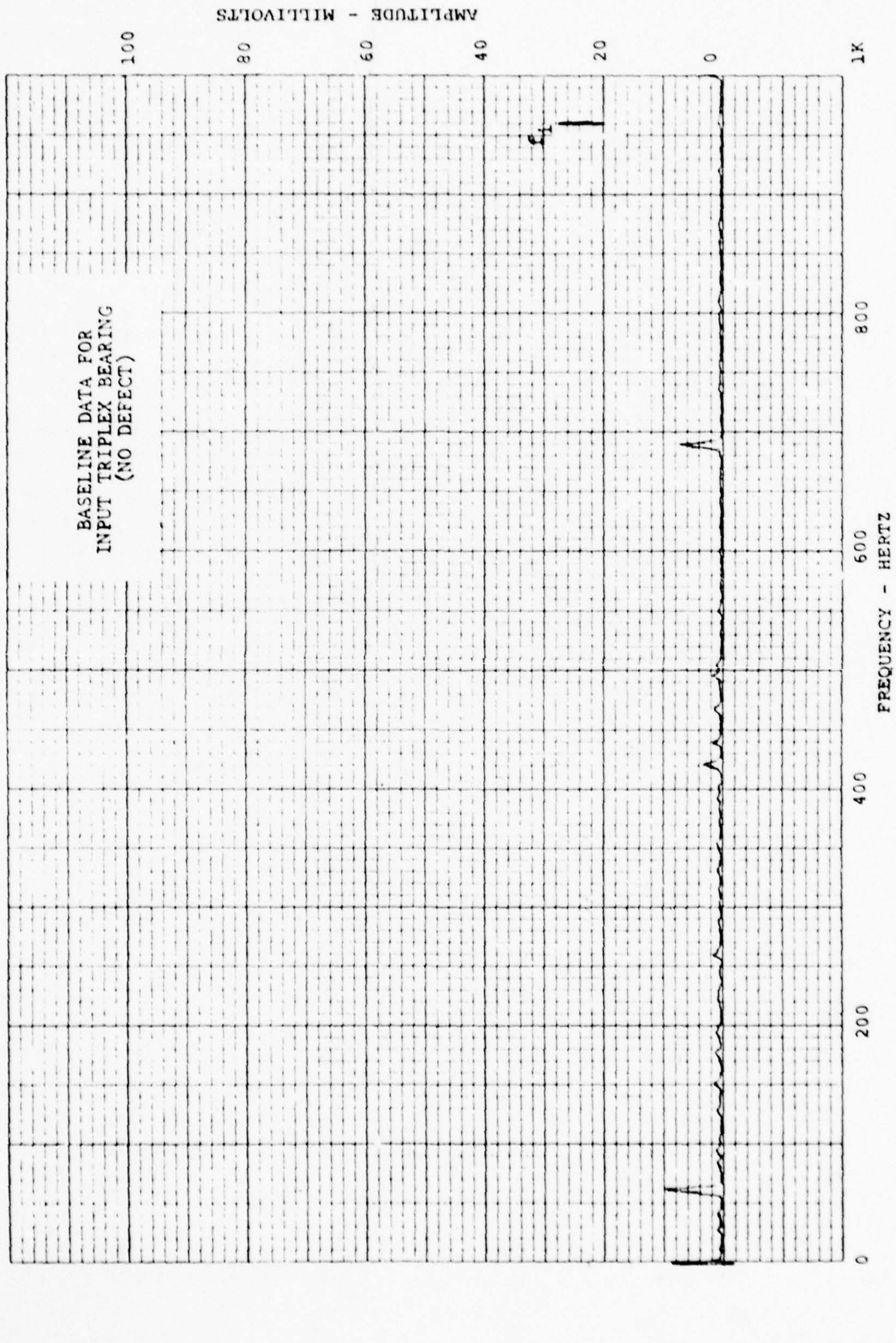

Figure B-6A. Demodulated signal spectrum - no transmission input bearing defect.

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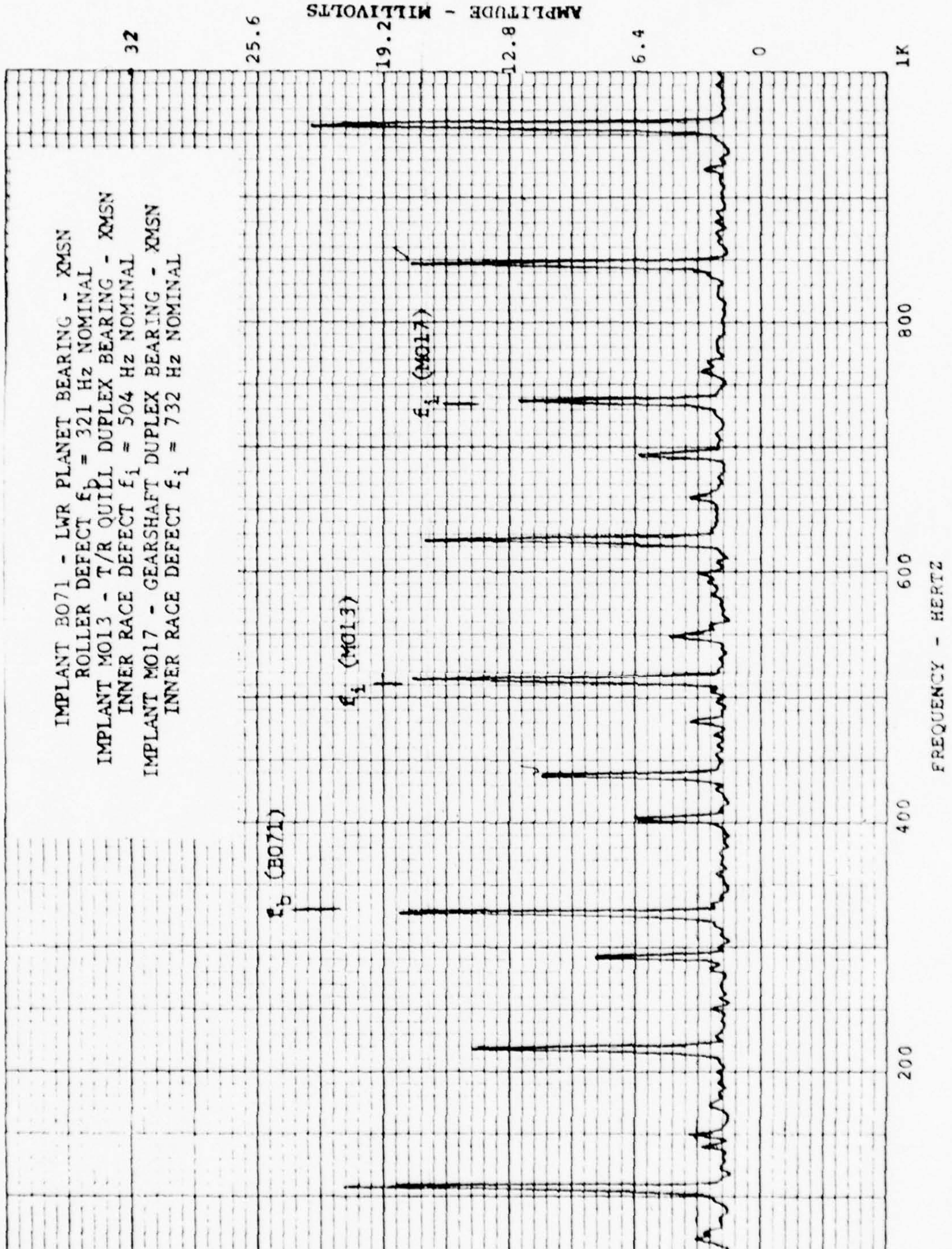

Figure B-7. Demodulated signal spectrum - multiple transmission defects.

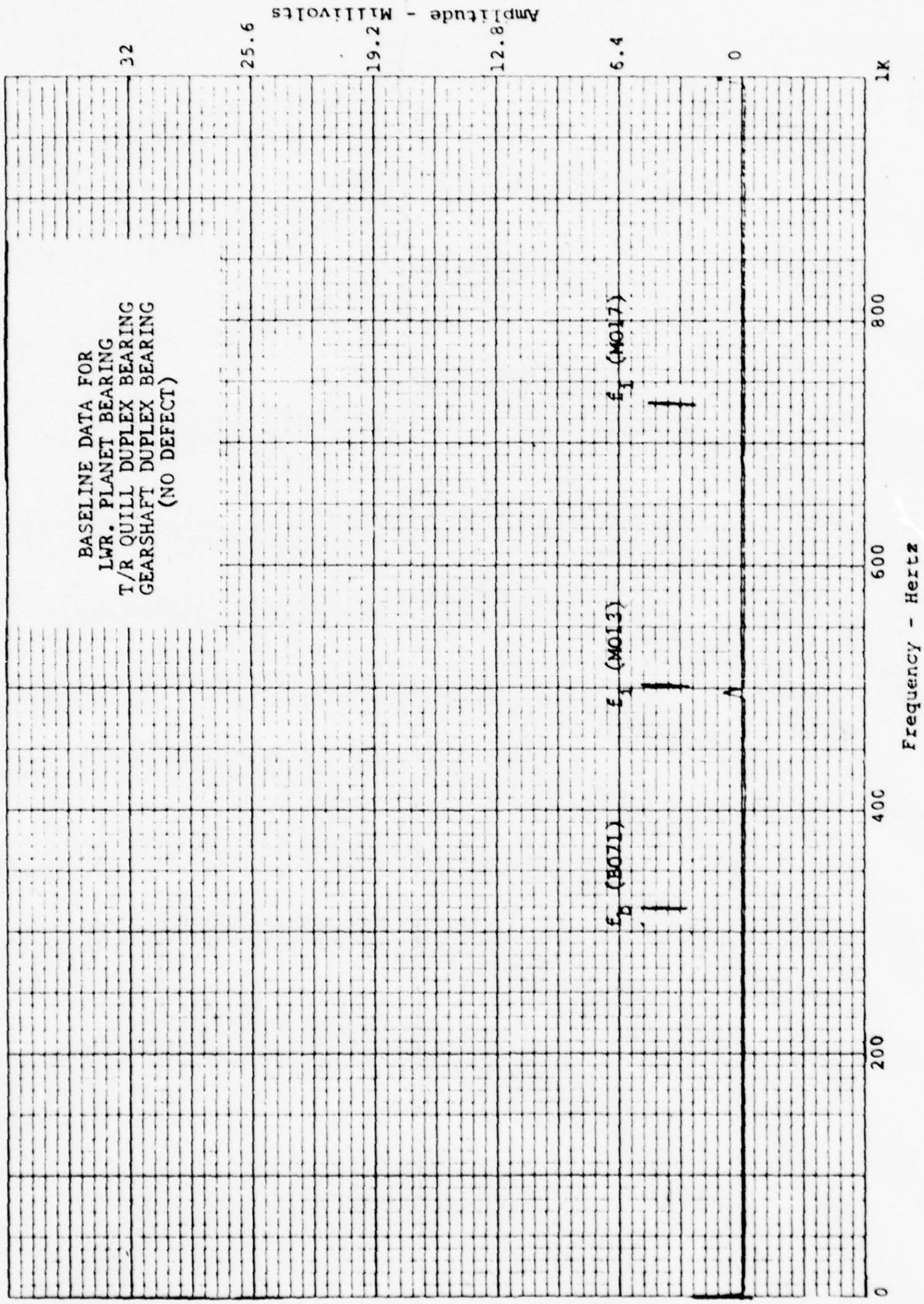

Figure B-7A. Demodulated signal spectra - no transmission defect.

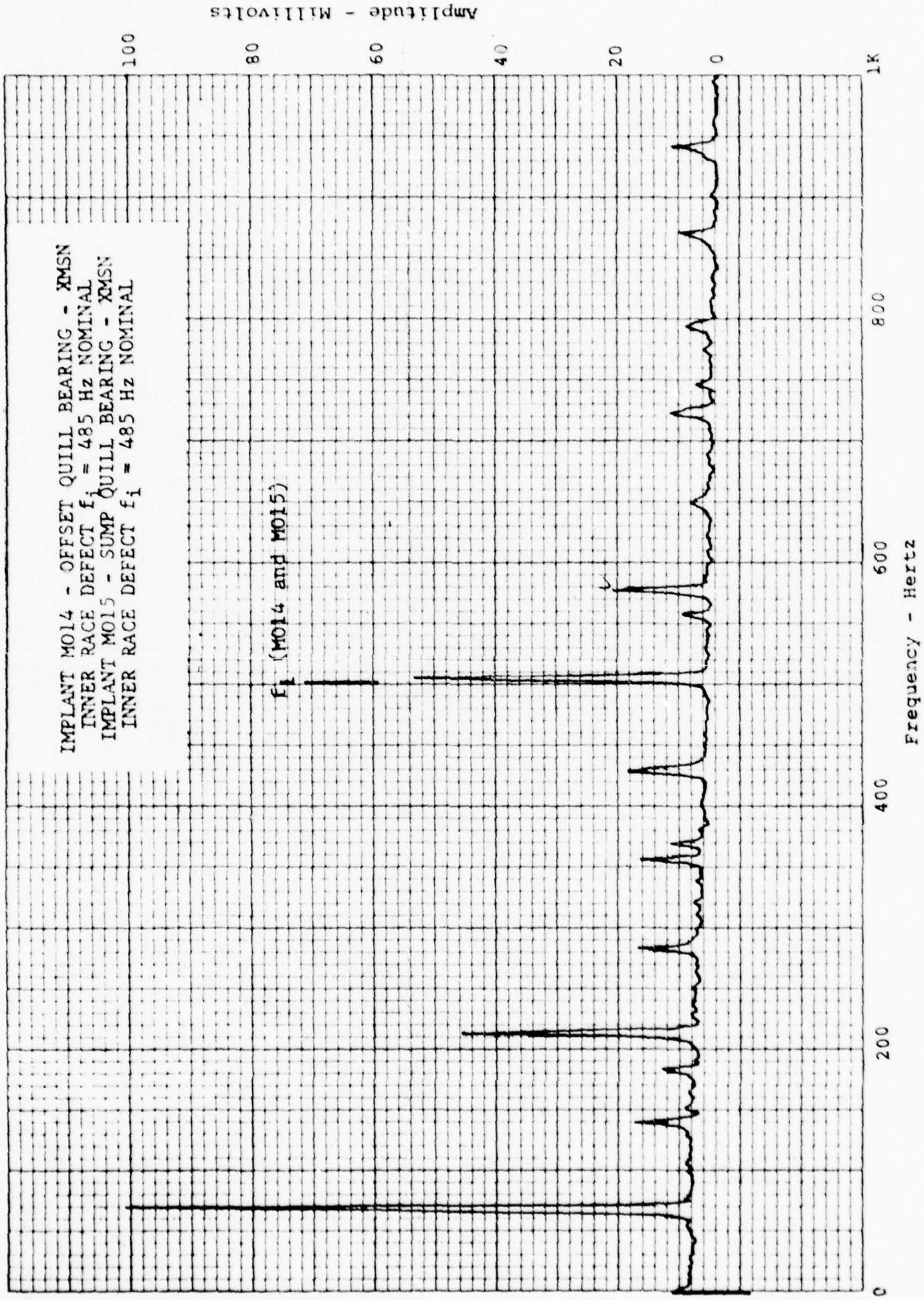

Figure B-8. Demodulated signal spectrum - multiple transmission defects.

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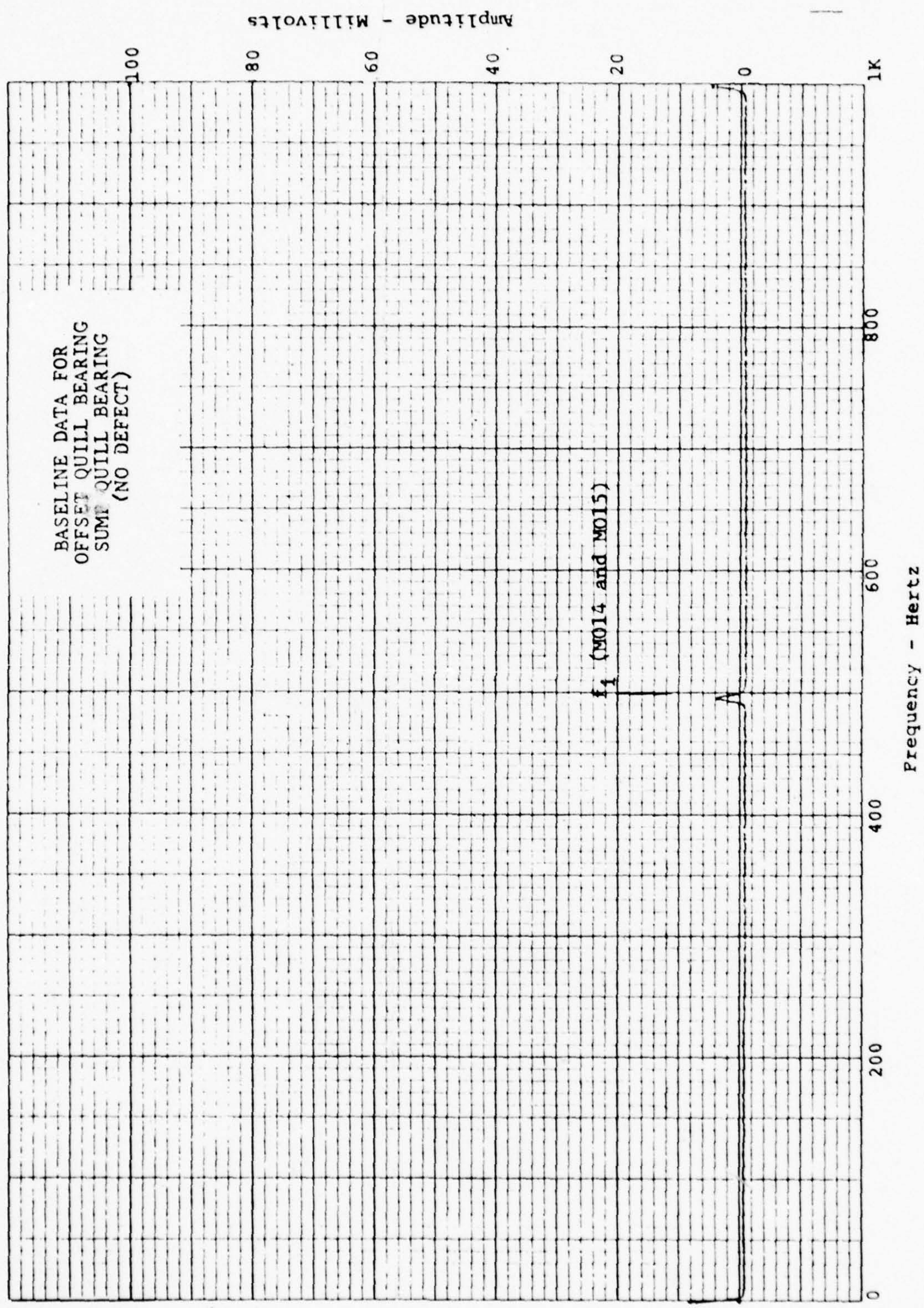

Figure B-8A. Demodulated signal spectrum - no transmission defect.

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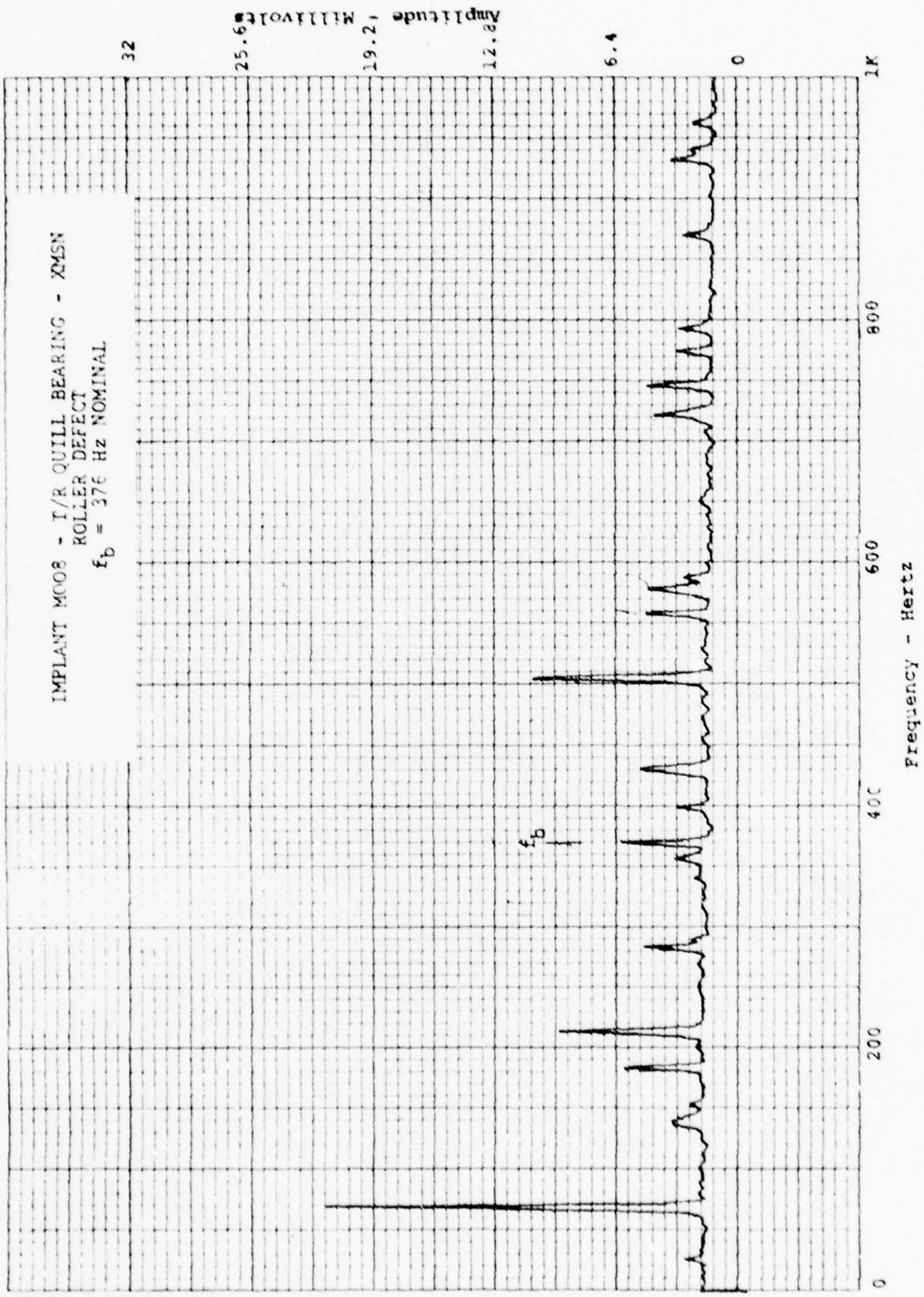

Figure B-9. Demodulated signal spectrum - T/R quill defect.

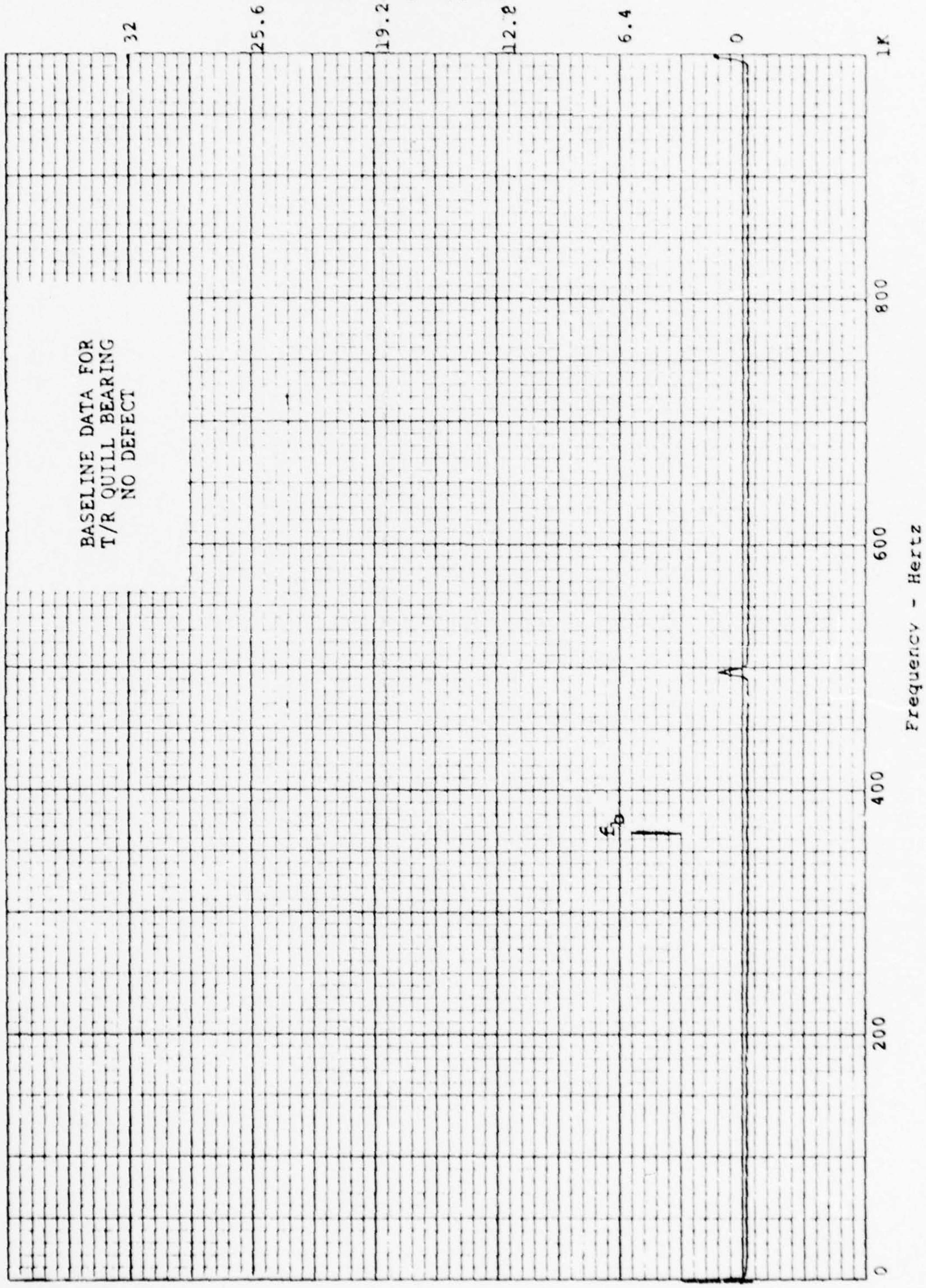

Figure B-9A. Demodulated signal spectrum - no T/R quill defect.

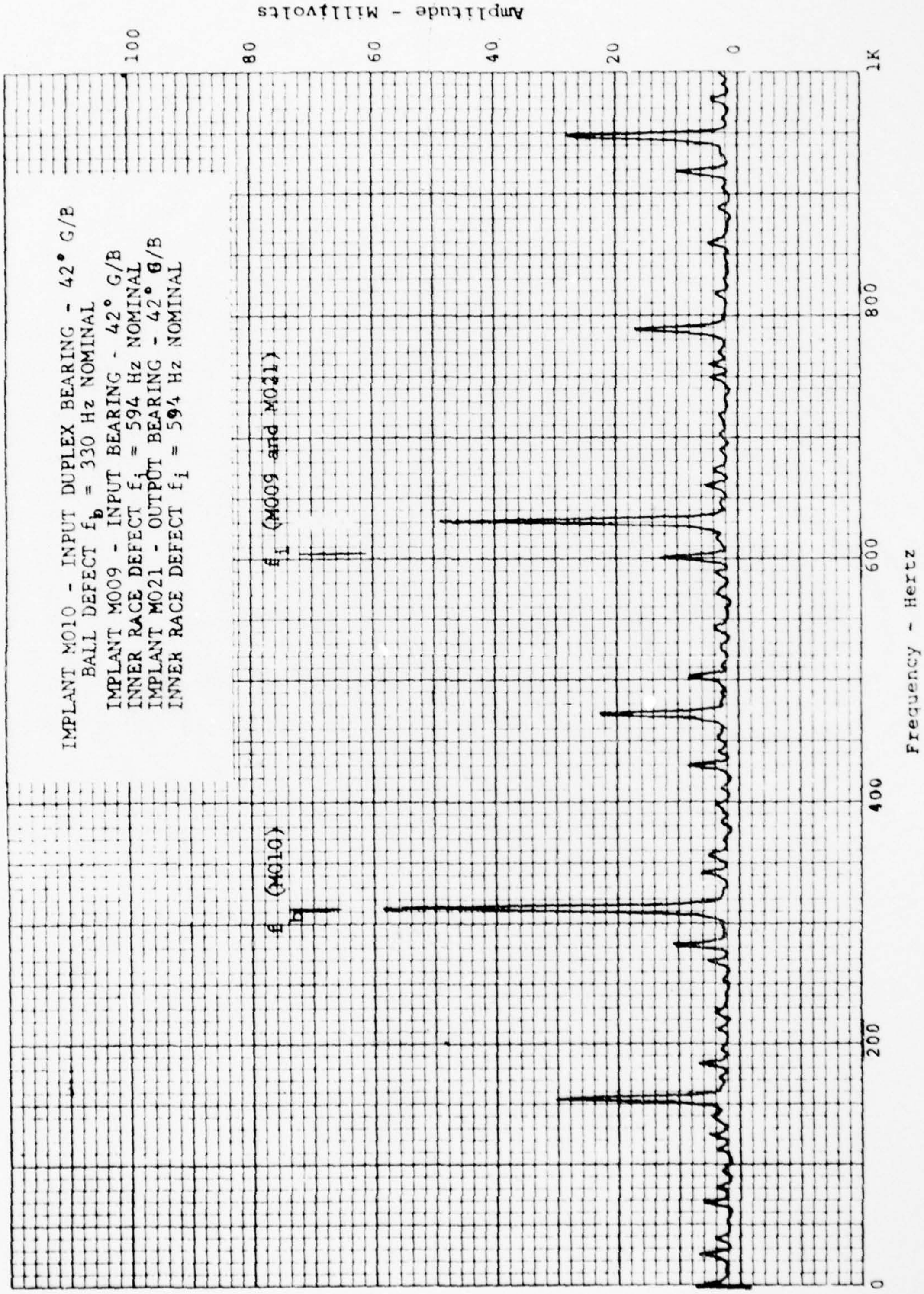

Figure B-10. Demodulated signal spectrum - multiple 42° gearbox defects.

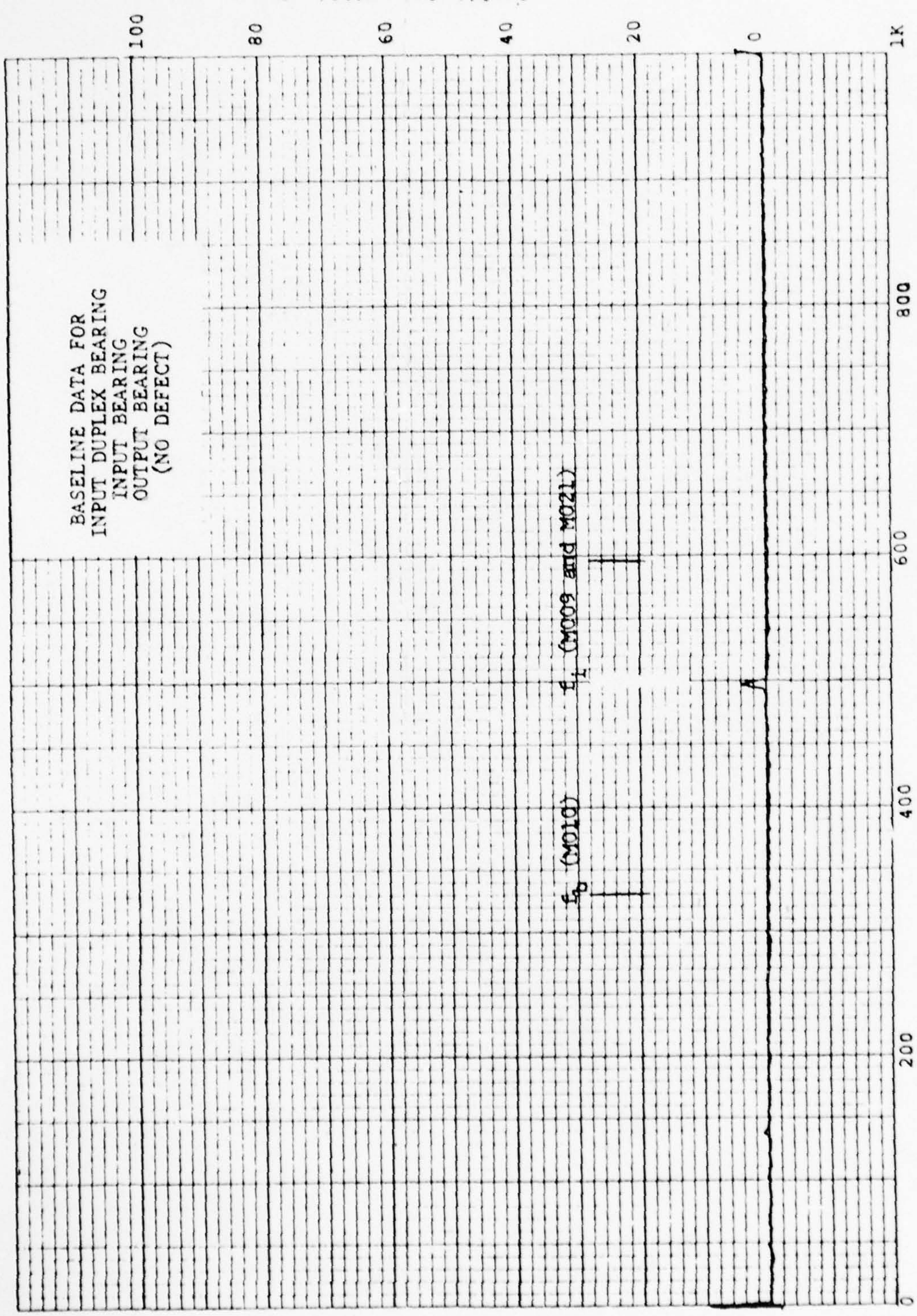

Figure B-10A. Demodulated signal spectrum - no 42° gearbox defect.

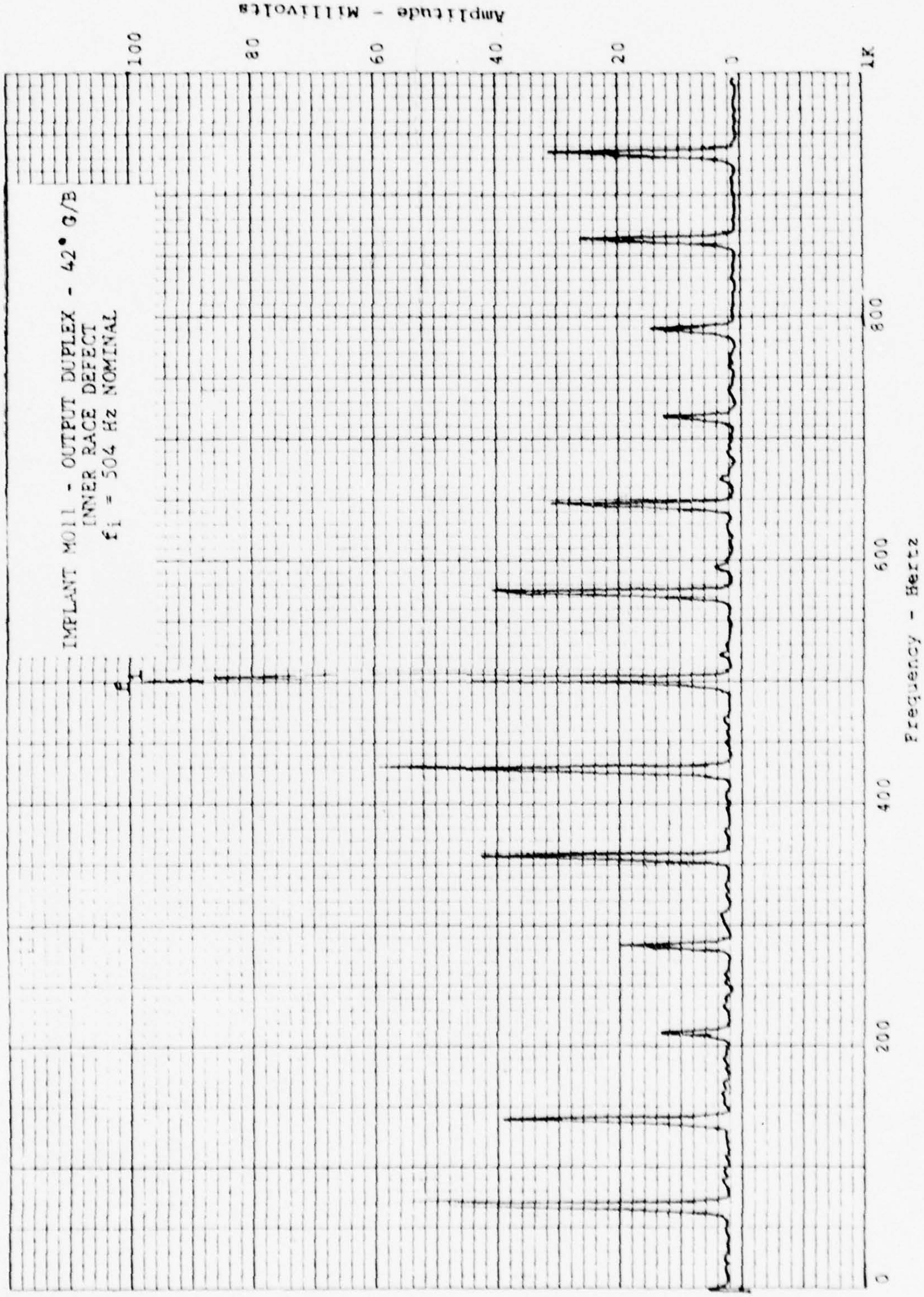

Figure B-11. Demodulated signal spectrum - 42° gearbox output defect.

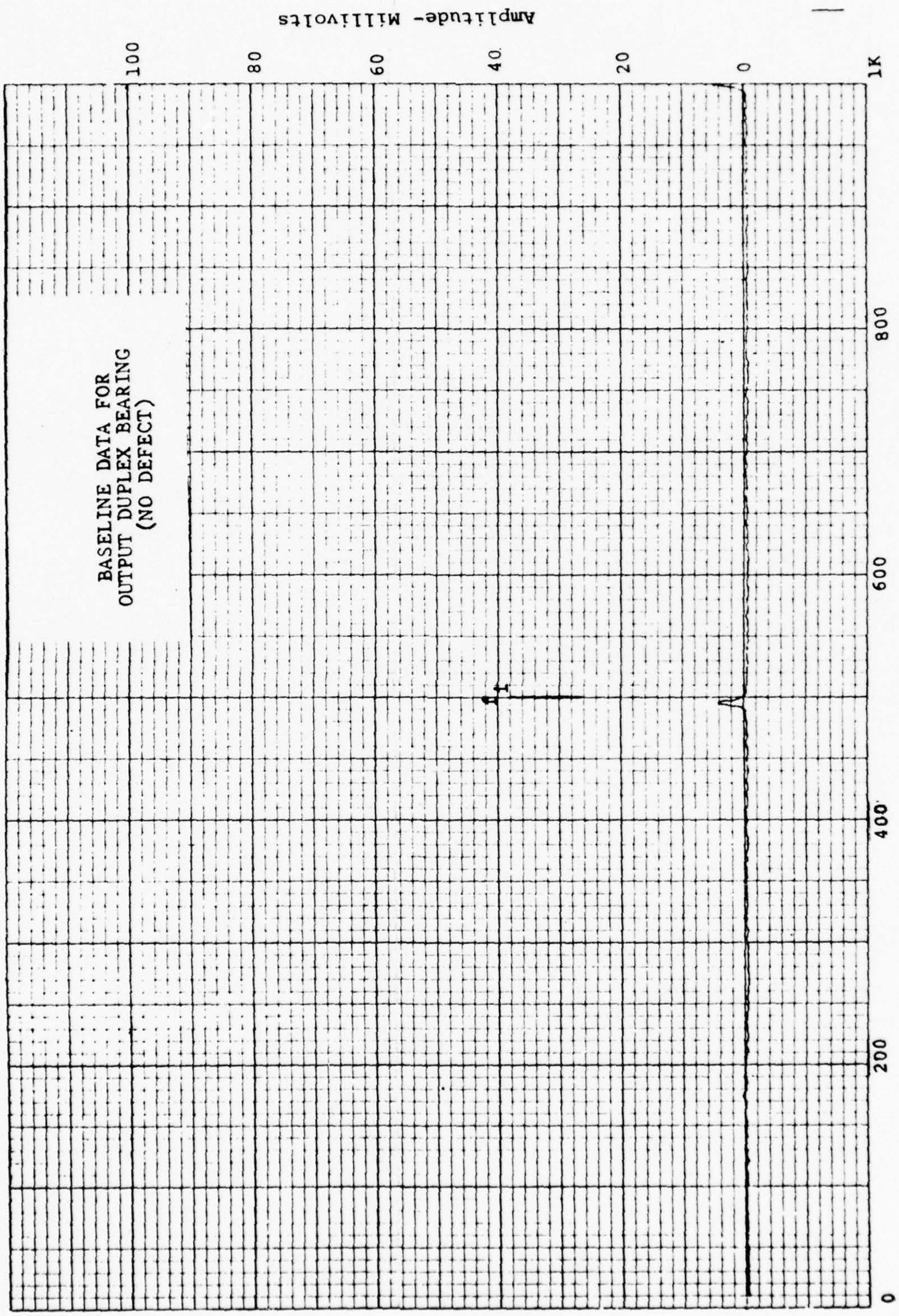

Figure B-11A. Demodulated signal spectrum - no 42° gearbox output defect.

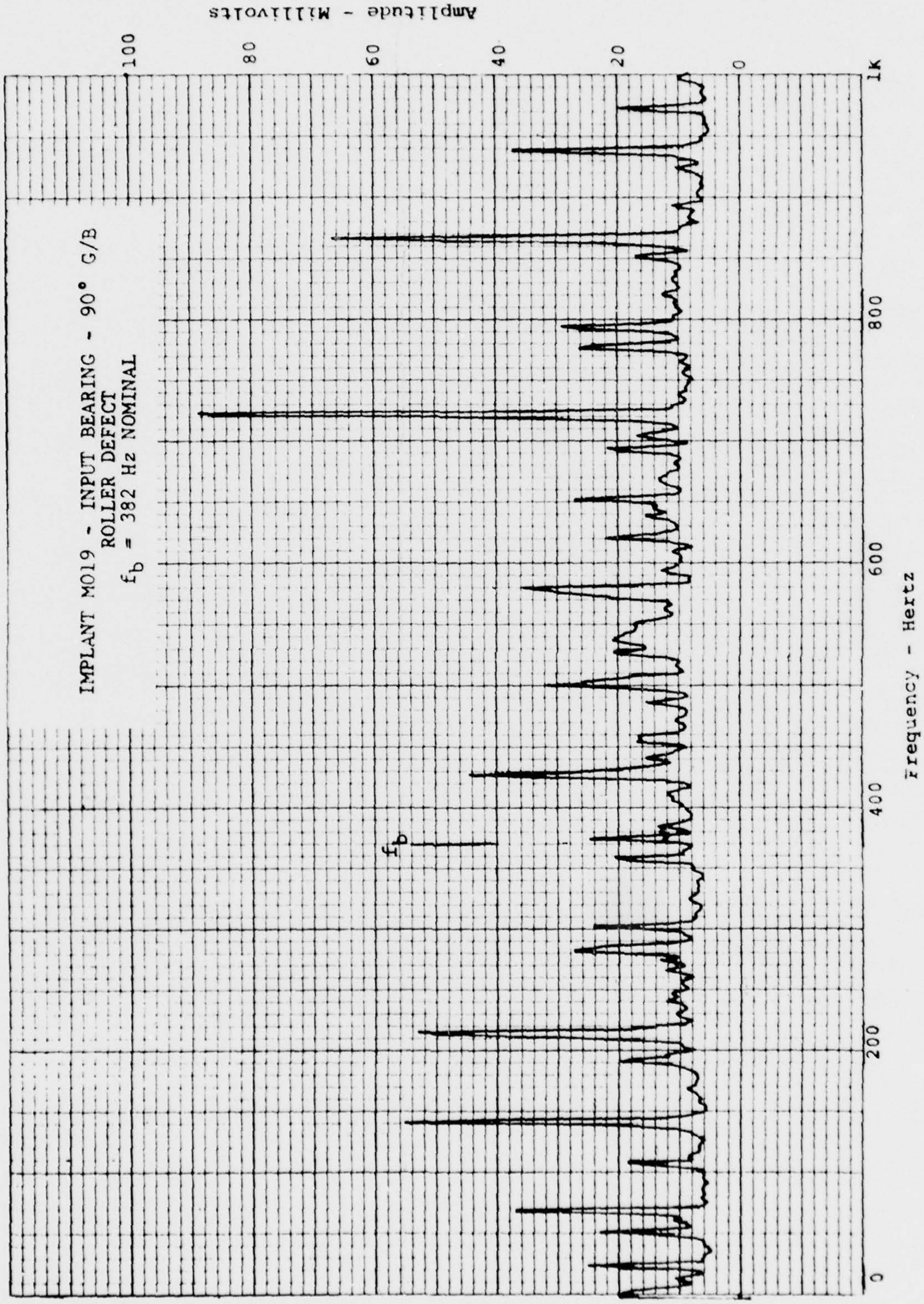

Figure B-12. Demodulated signal spectrum - 90° gearbox input defect.

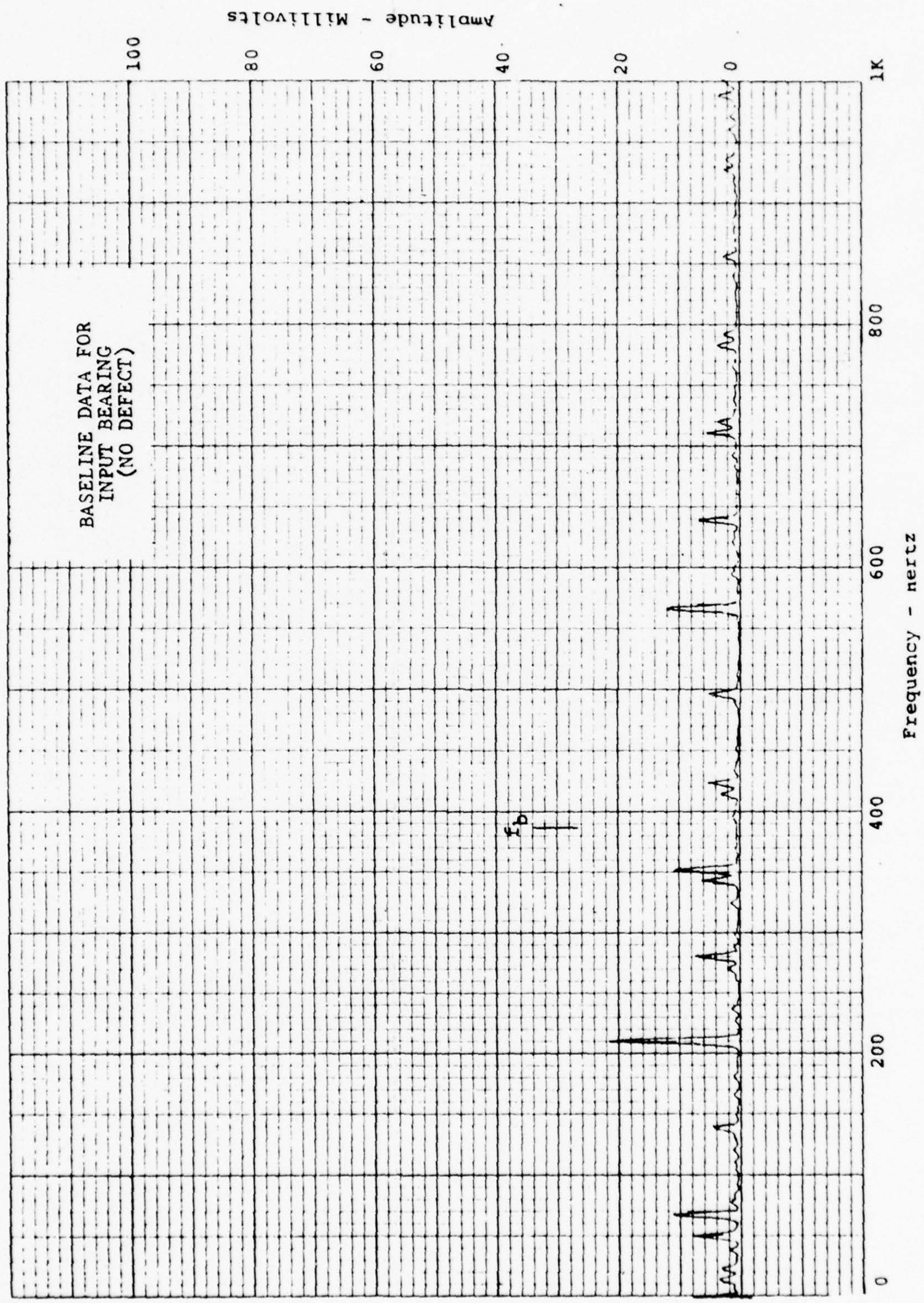

Figure B-12A. Demodulated signal spectrum - no 90° gearbox defect.

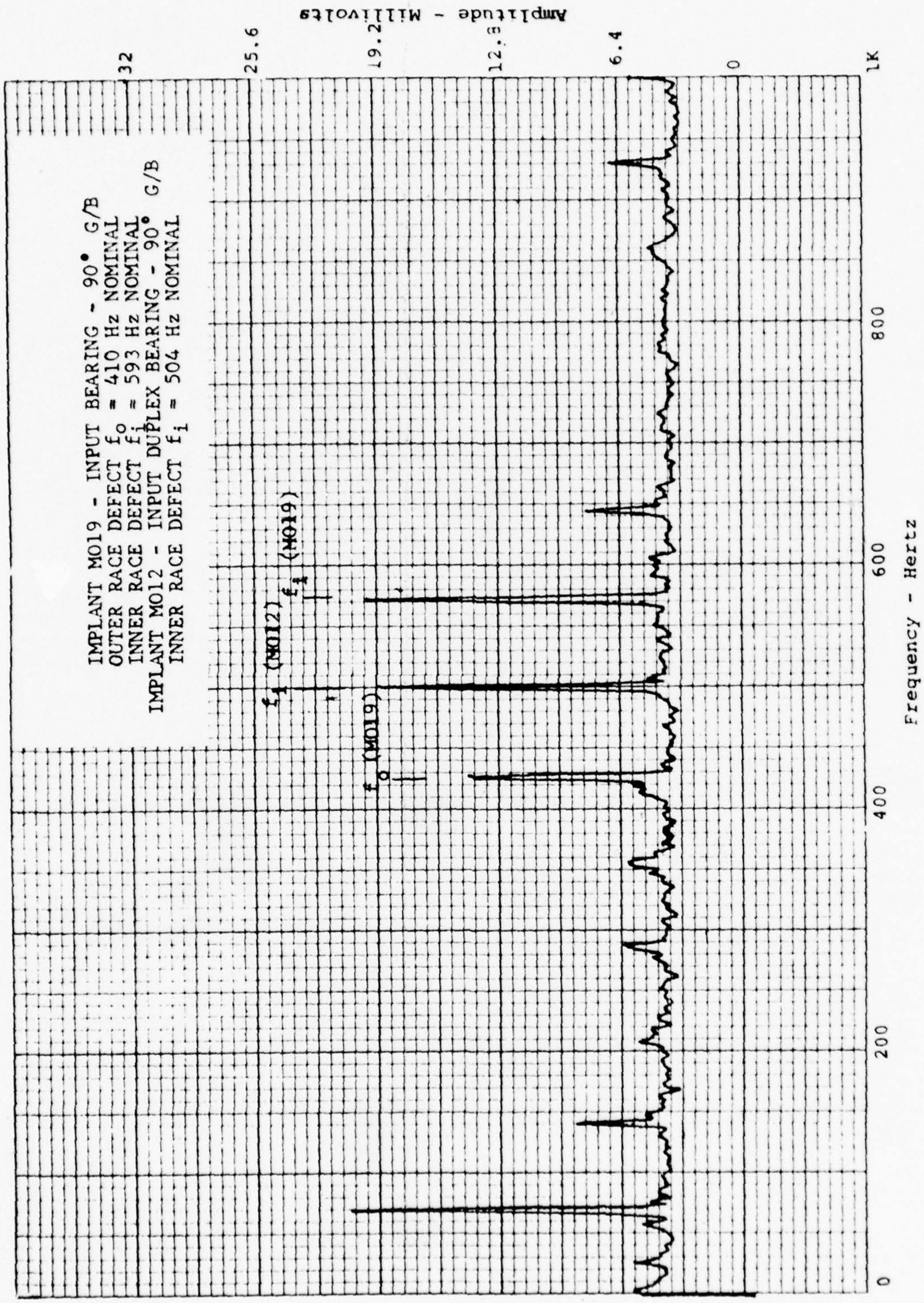

Figure B-13. Demodulated signal spectrum - multiple 90° gearbox input defects.

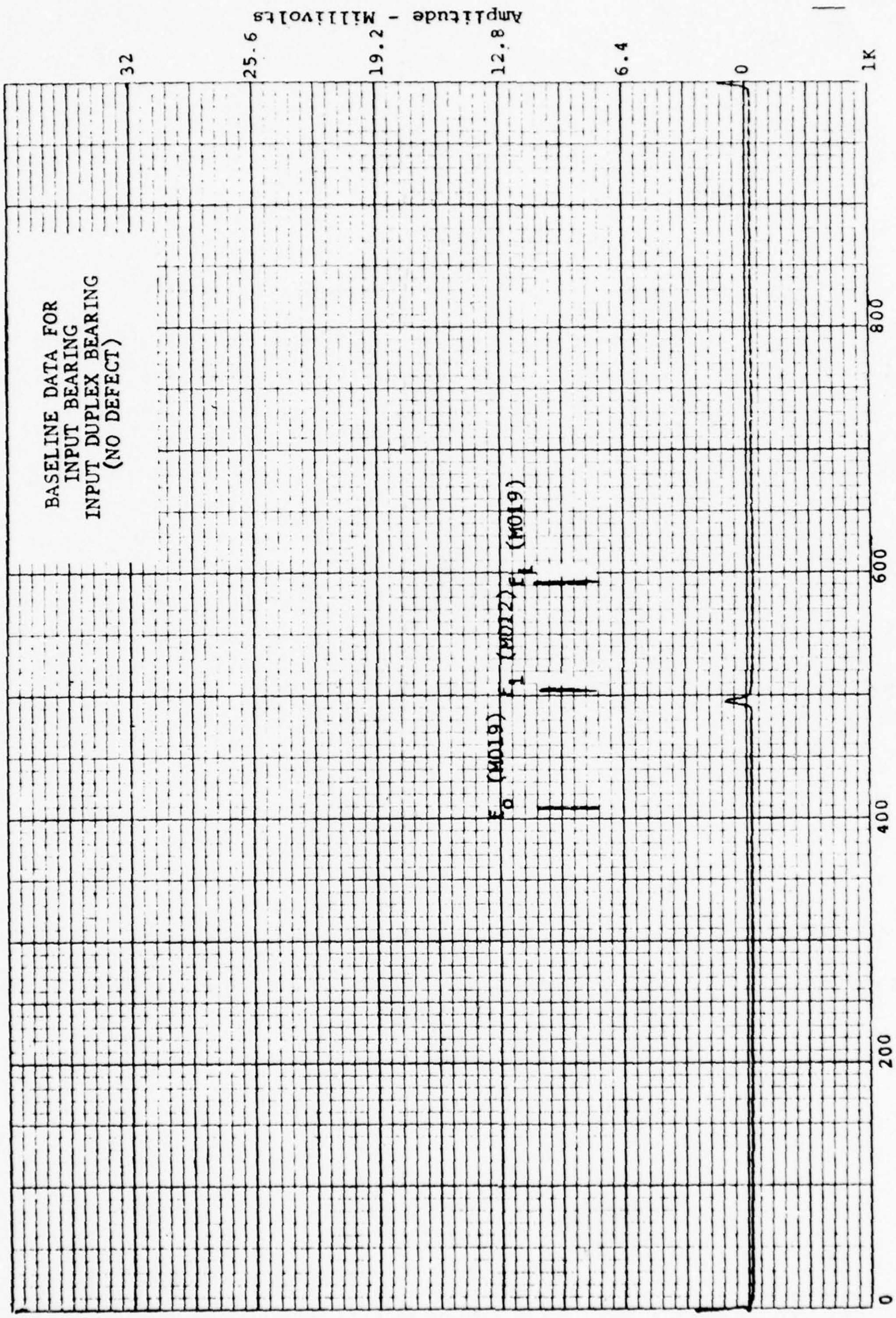

Figure B-13A. Demodulated signal spectrum - no 90° gearbox defect.

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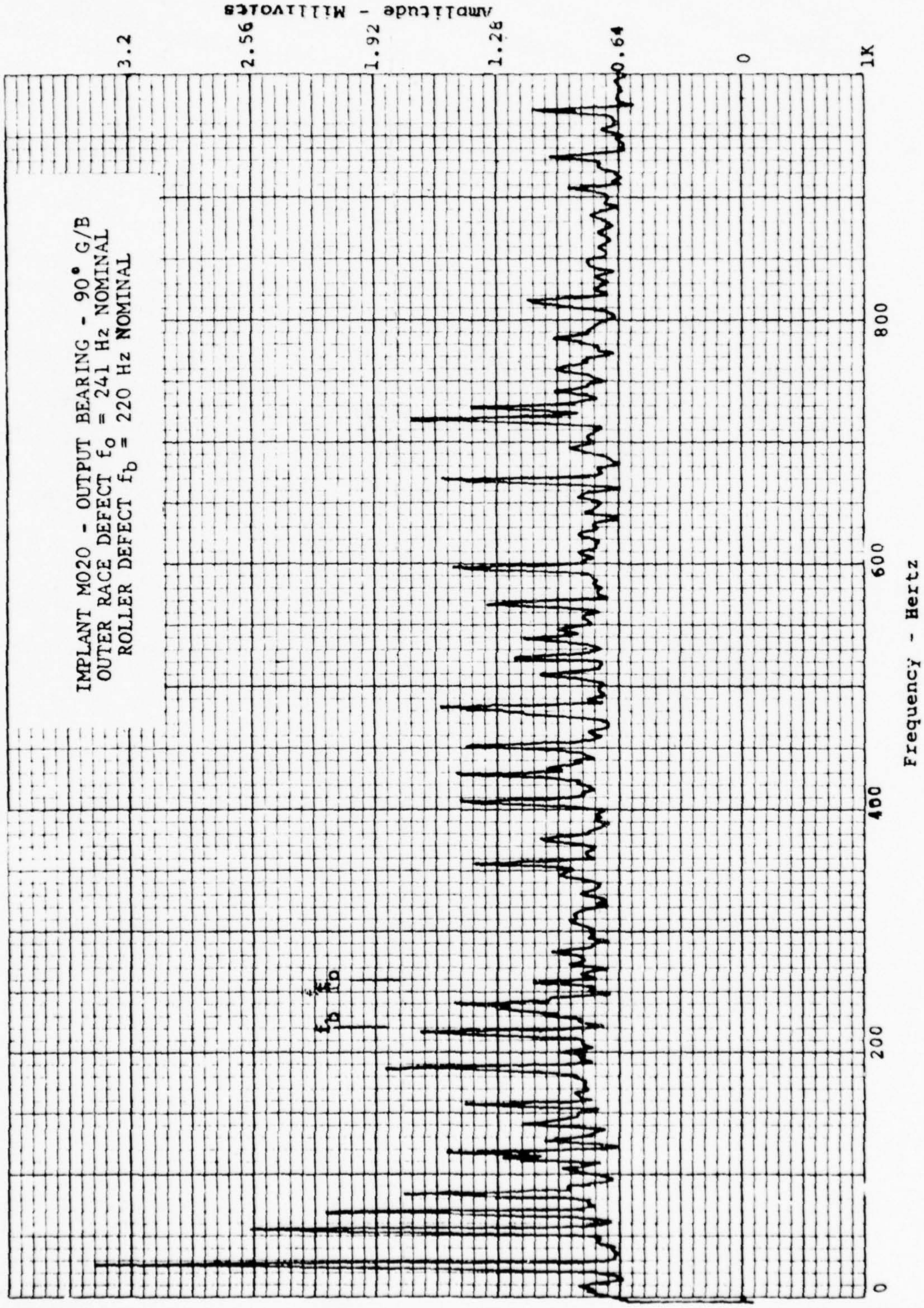

Figure B-14. Demodulated signal spectrum - 90° gearbox output defect.

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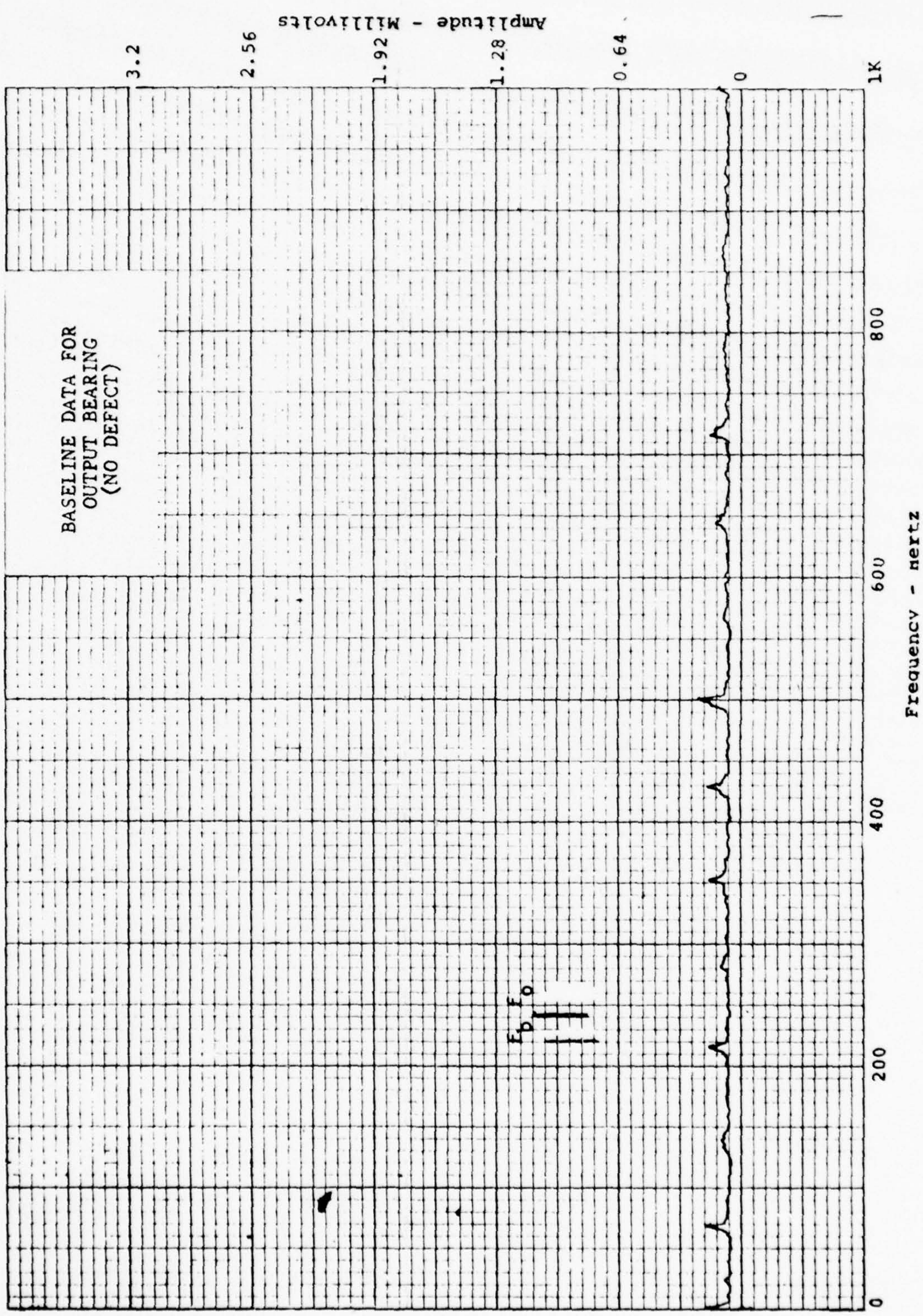

Figure B-14A. Demodulated signal spectrum - no 90° gearbox defect.

TABLE B-II

UNDOCUMENTED CATEGORY "B" BEARING DETECTION

Implant P/N	Degradation	Defect Frequency	Remarks
MAIC-007	Inner Race	573 fi	
MAIC-010	Inner Race	504 fi	
MAIC-012	Outer Race	357 fi	
MAIC-012	Ball	428 fb	Not verified
MAIC-015	Ball	393 fb	
MAIC-016	Ball	214 fb	
MAIC-017	Outer Race	606 fo	
MAIC-018	Ball	594 fb	
MAIC-018	Outer Race	990 fo	Not verified
MAIC-020	Inner Race	310 fi	
BHC-071	Inner Race	494 fi	
BHC-124	Ball	39 fb	Not verified
BHC-124	Inner Race	61 fi	

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B-2.0 GEAR DEFECT VIBRATION MONITORING

B-2.1 Discussion

The fundamental gear mesh frequency, and sidebands that correspond to the one-per-revolution of the gear shaft, are predominant frequencies noted during gear operation. As a gear fault becomes present, the fundamental gear mesh frequency amplitude decreases and the amplitude of the sidebands increases. The decrease in relative power of the fundamental with redistribution of the power into sideband energy is characteristic of frequency modulation (FM). By FM demodulation of the fundamental gear mesh frequency of the vibration sensor signal, the redistribution of the side-band energy can be measured and defective gears can be identified.

A block diagram of the gear defect detection system is presented in Figure B-15. The accelerometer signal between 1 and 80 kHz is provided to the phase lock loop. The phase lock loop center frequency is set at the fundamental gear mesh frequency of the gear monitored with a band width encompassing ± 5 sidebands which are multiples of the gear shaft rotation speed. The demodulated signal is then spectrum analyzed. Significant spectrum peaks at the sideband frequencies indicate that a gear fault is present. The scope and x-y plotter are used to monitor and capture the data signals.

An automatic monitor, shown in Figure B-16, was developed to replace the spectrum analyzer. This monitor is similar to the one developed for bearing faults, except the counter circuit used to eliminate noise and spurious signals was not optimized. The demodulated vibration signal is provided to the RMS-to-DC converter and peak detector. The DC output of the RMS and peak detector is ratioed and compared in the comparator, which activates the fault indicator.

B-2.2 Results

The data presented was obtained from the two B&K Model 4344 accelerometers located on the 42-degree gearbox during the first test block of the Removal Confidence Test. The spectral plots of Figures B-17 to B-23 taken at the output of the phase lock loop show that the gear mesh fundamental is frequency modulated by the one-per-revolution of the gear shaft frequency. The gear implanted during these test runs failed after 90 hours. The plots show a generally increasing sideband energy level as the test progresses. Presumably, the condition of the gears was rapidly deteriorating during this period. The decrease in sideband signal at 90 hours probably indicates that the gear was broken by this time, with consequent change in the signal spectrum. The gearbox was still transmitting power when the test was stopped and the broken gear discovered.

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The tests to date have been limited to the 42-degree gearbox because of time available. Comparable 42-degree gearbox data was limited because many of the test tapes from the diagnostic program were not available, having been delivered to AVSCOM or Airesearch or MTI. Those available provided limited data because of the different accelerometers installed that consequently limited the vibration signal comparison. As a result the signal comparator ratio was not finalized or a noise elimination circuit developed as presented with the bearing circuit monitor.

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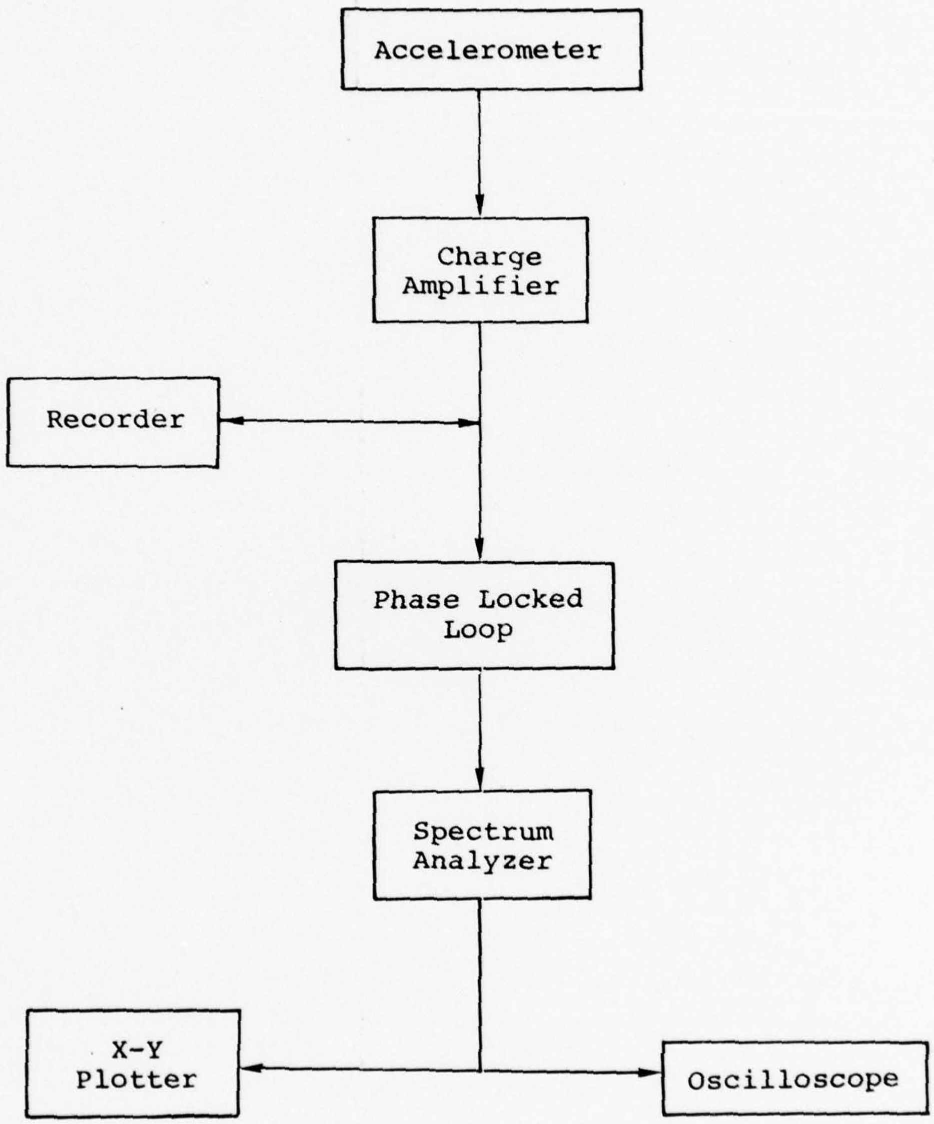

Figure B-15. Gear defect detection block diagram.

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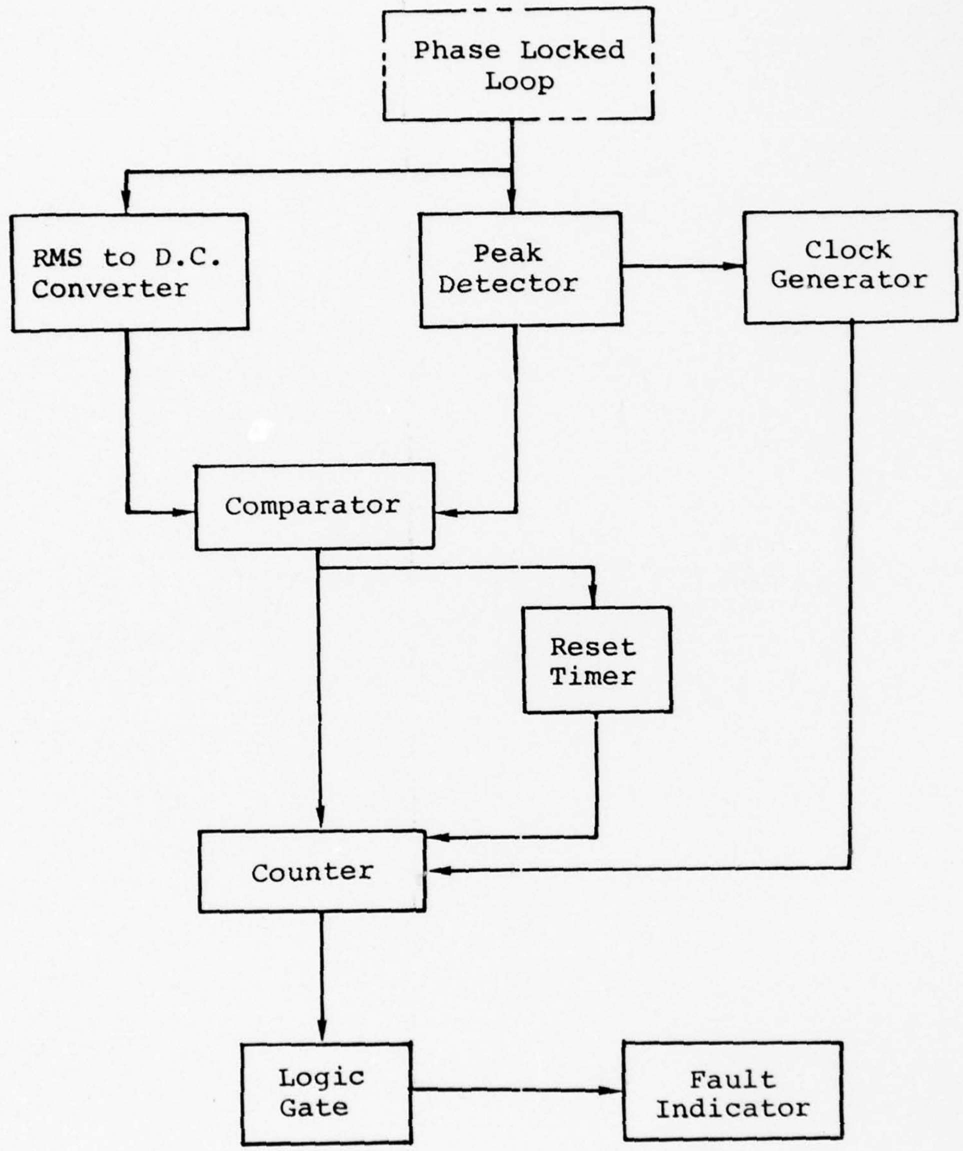

Figure B-16. Gear defect monitor block diagram.

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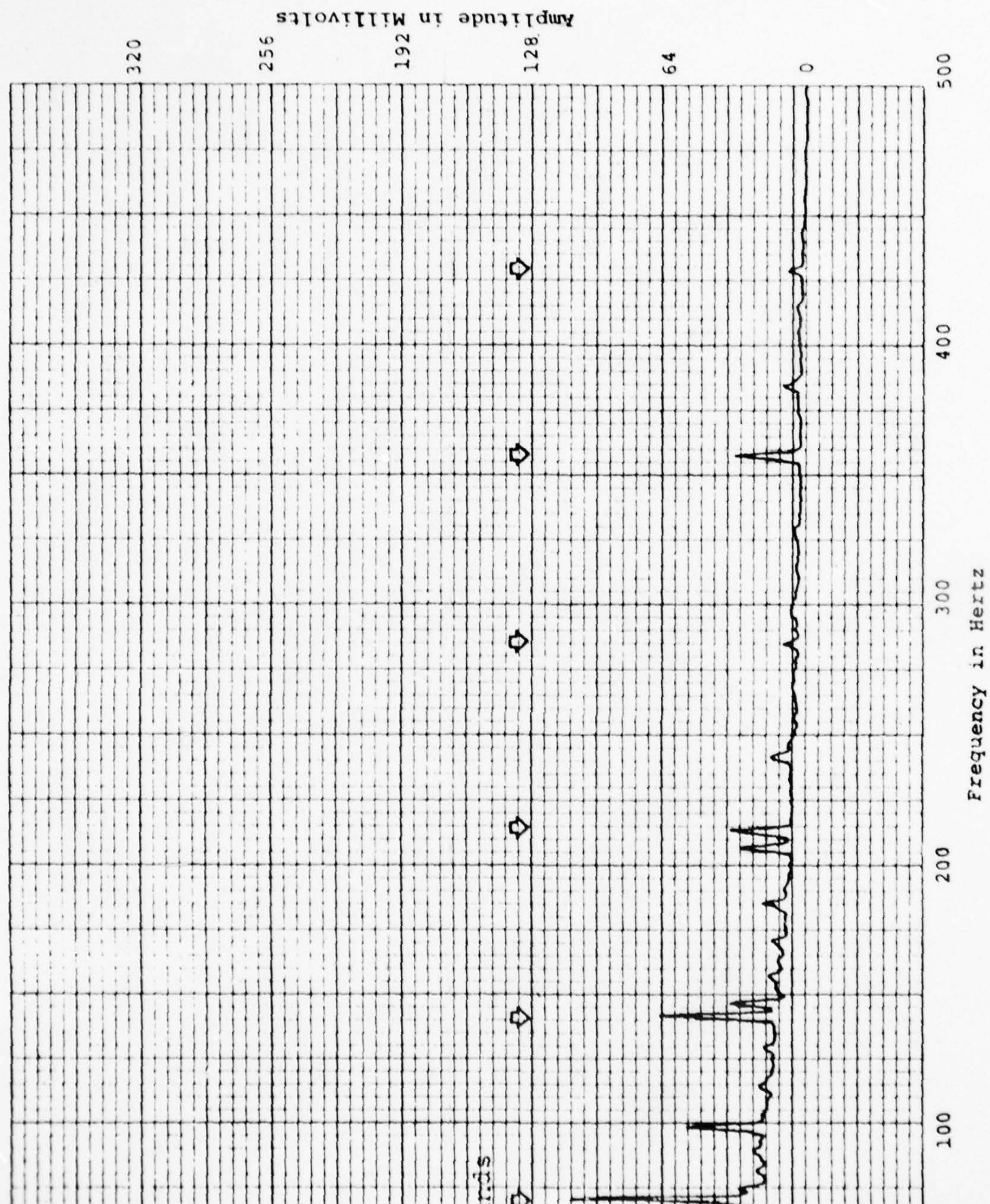

Figure B-17. Demodulated signal spectrum - 42° gearbox, t=45 hours.

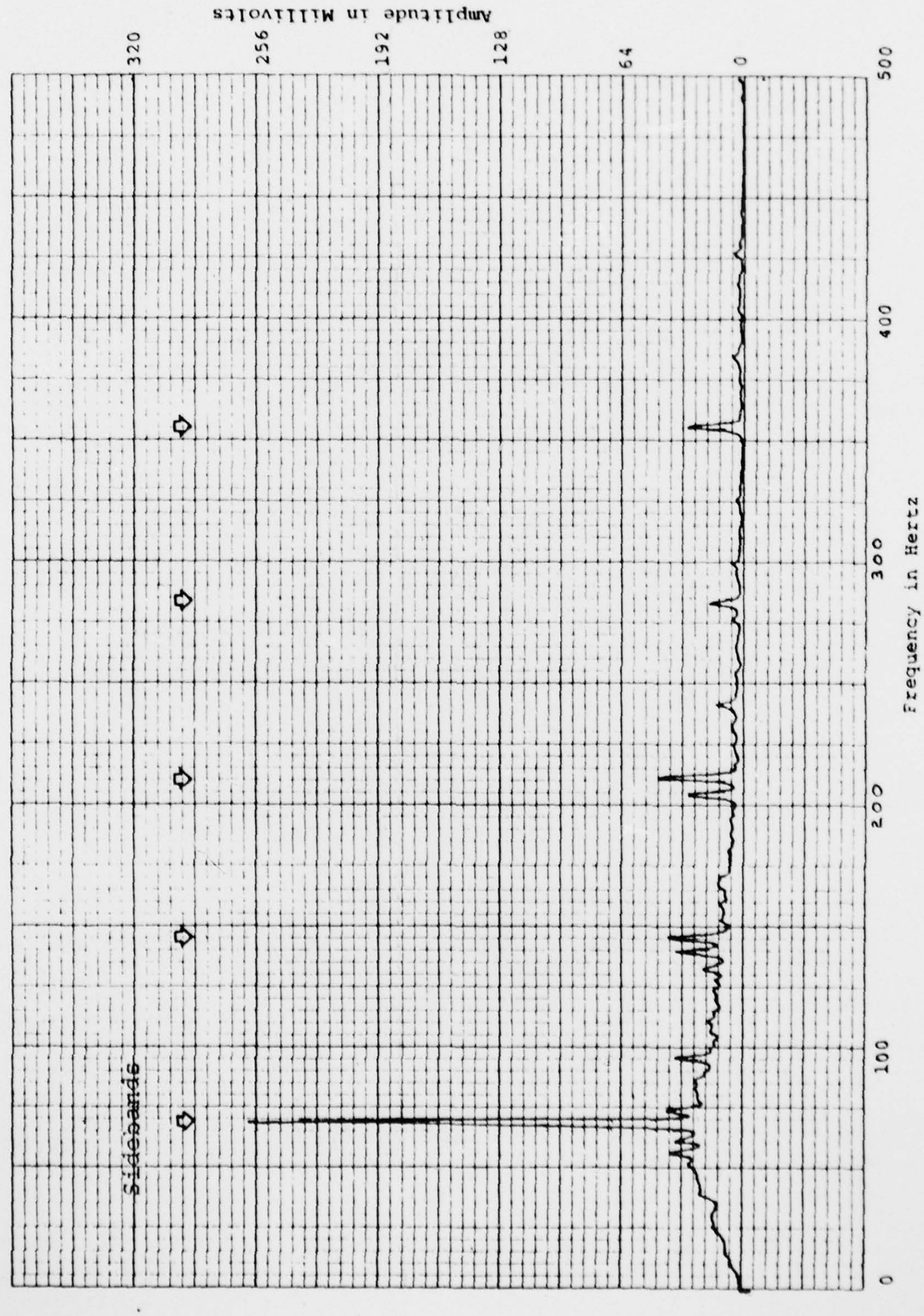

Figure B-18. Demodulated signal spectrum - 42° gearbox, t=50 hours.

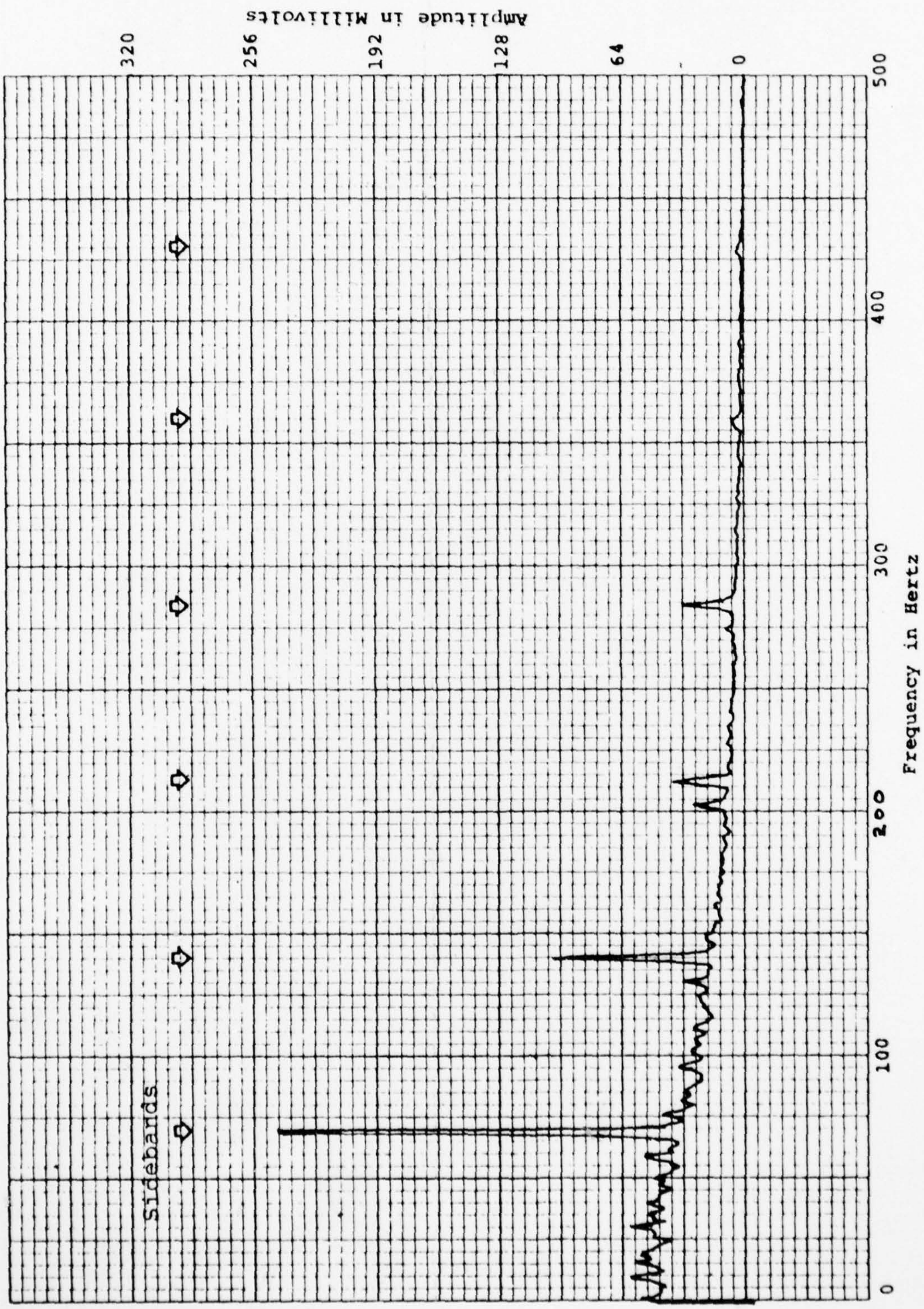

Figure B-19. Demodulated signal spectrum - 42° gearbox, t=60 hours.

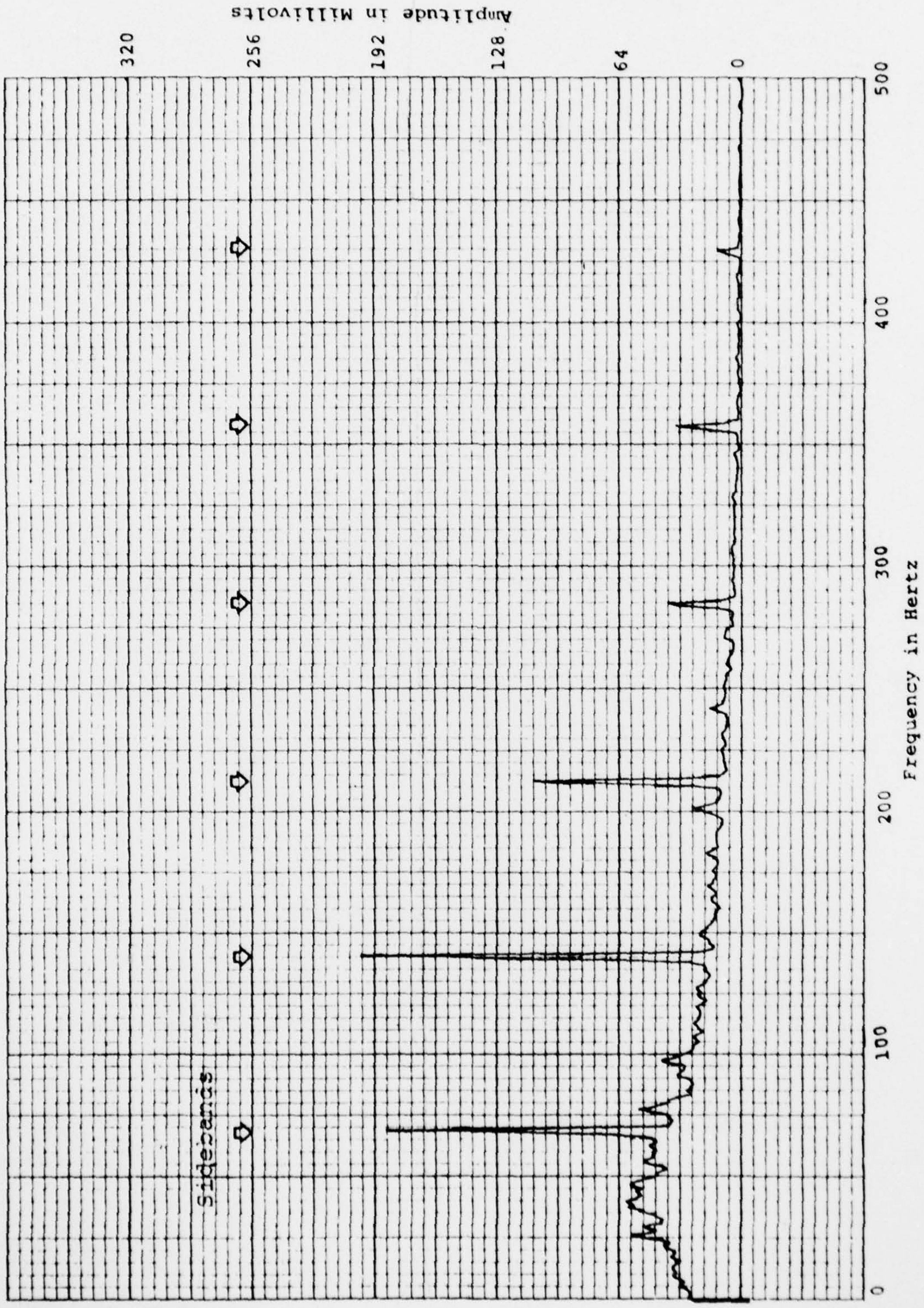

Figure B-20. Demodulated signal spectrum - 42° gearbox, t=64 hours.

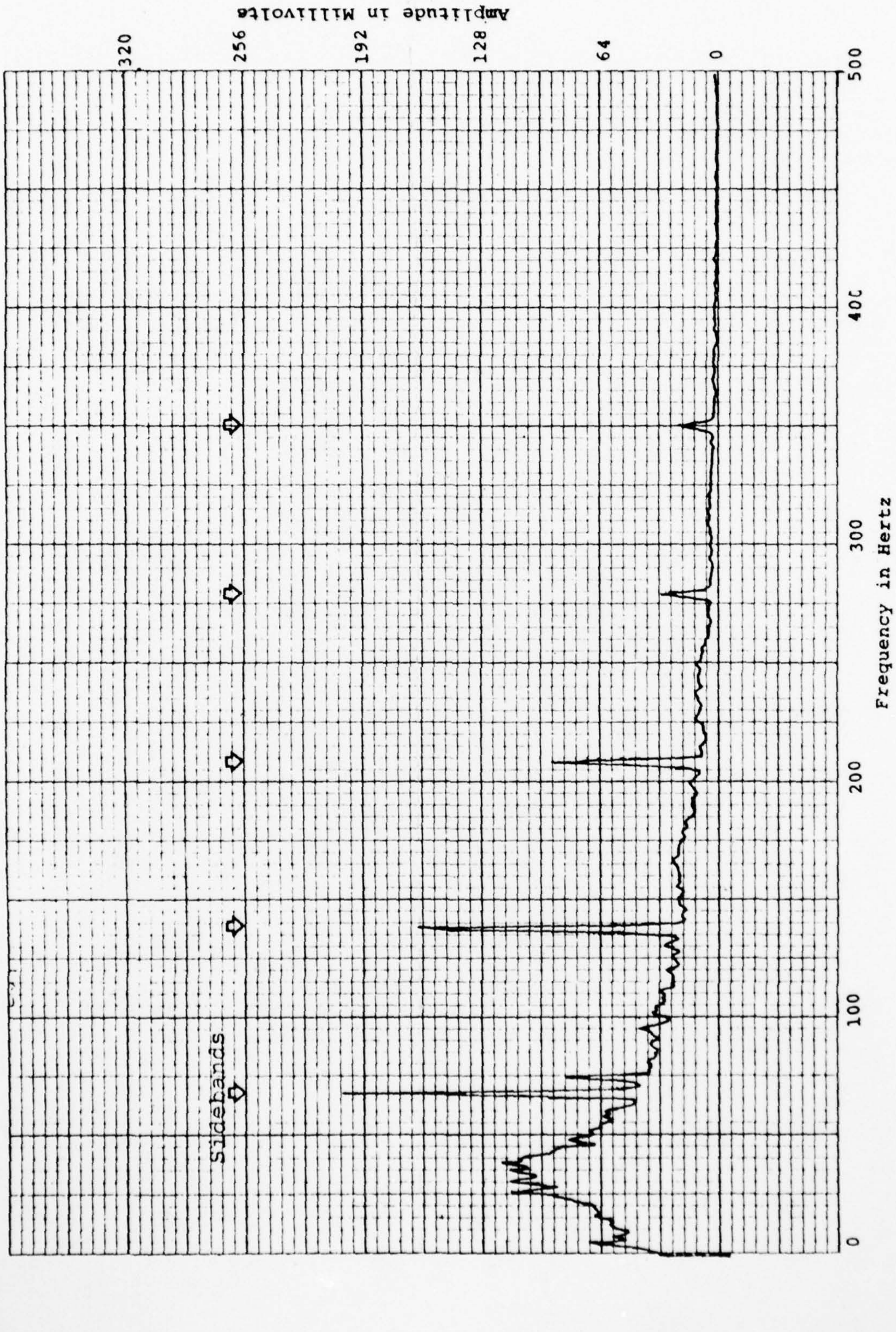

Figure B-21. Demodulated signal spectrum - 42° gearbox, t=70 hours.

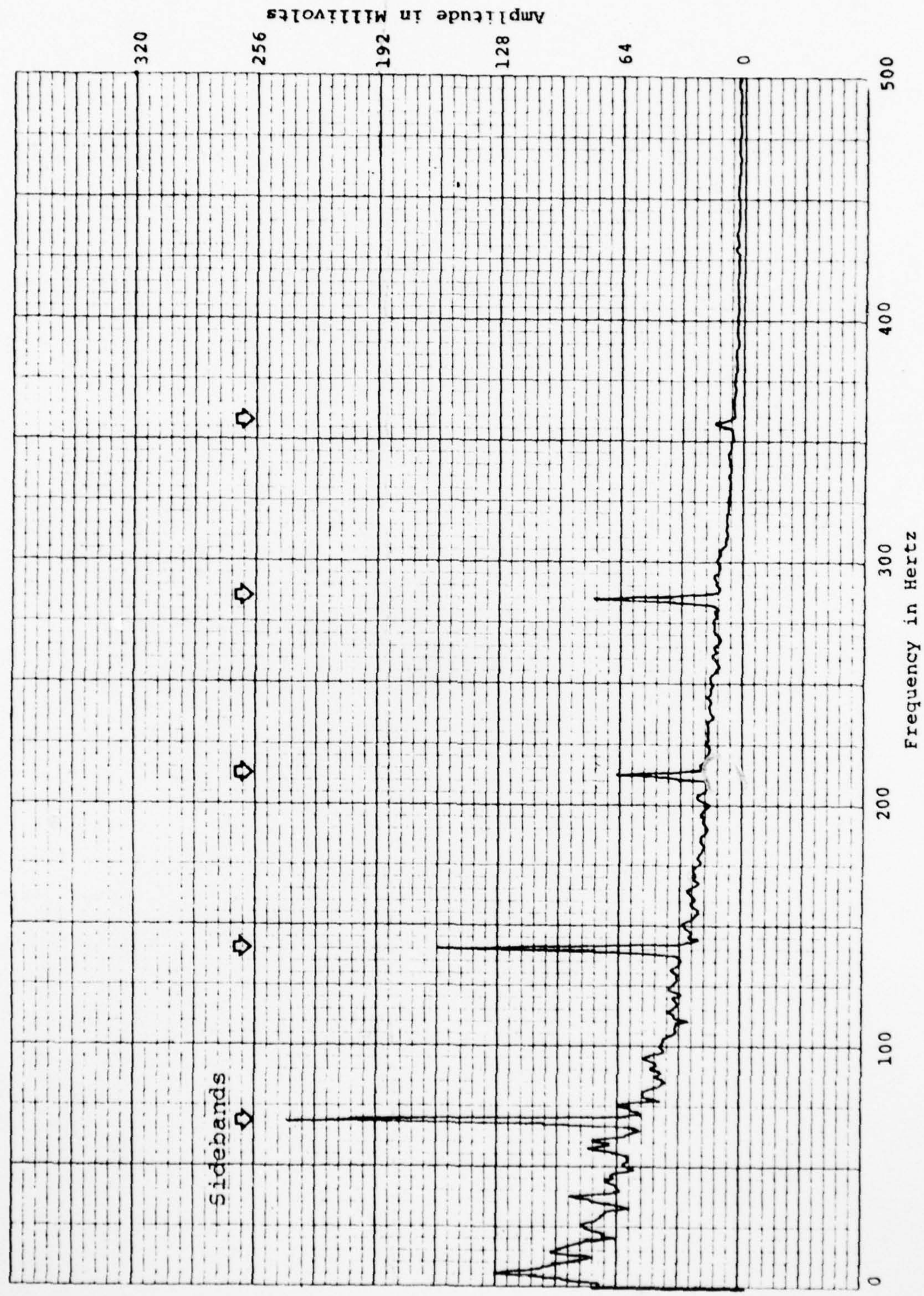

Figure B-22. Demodulated signal spectrum - 42° gearbox, t=80 hours.

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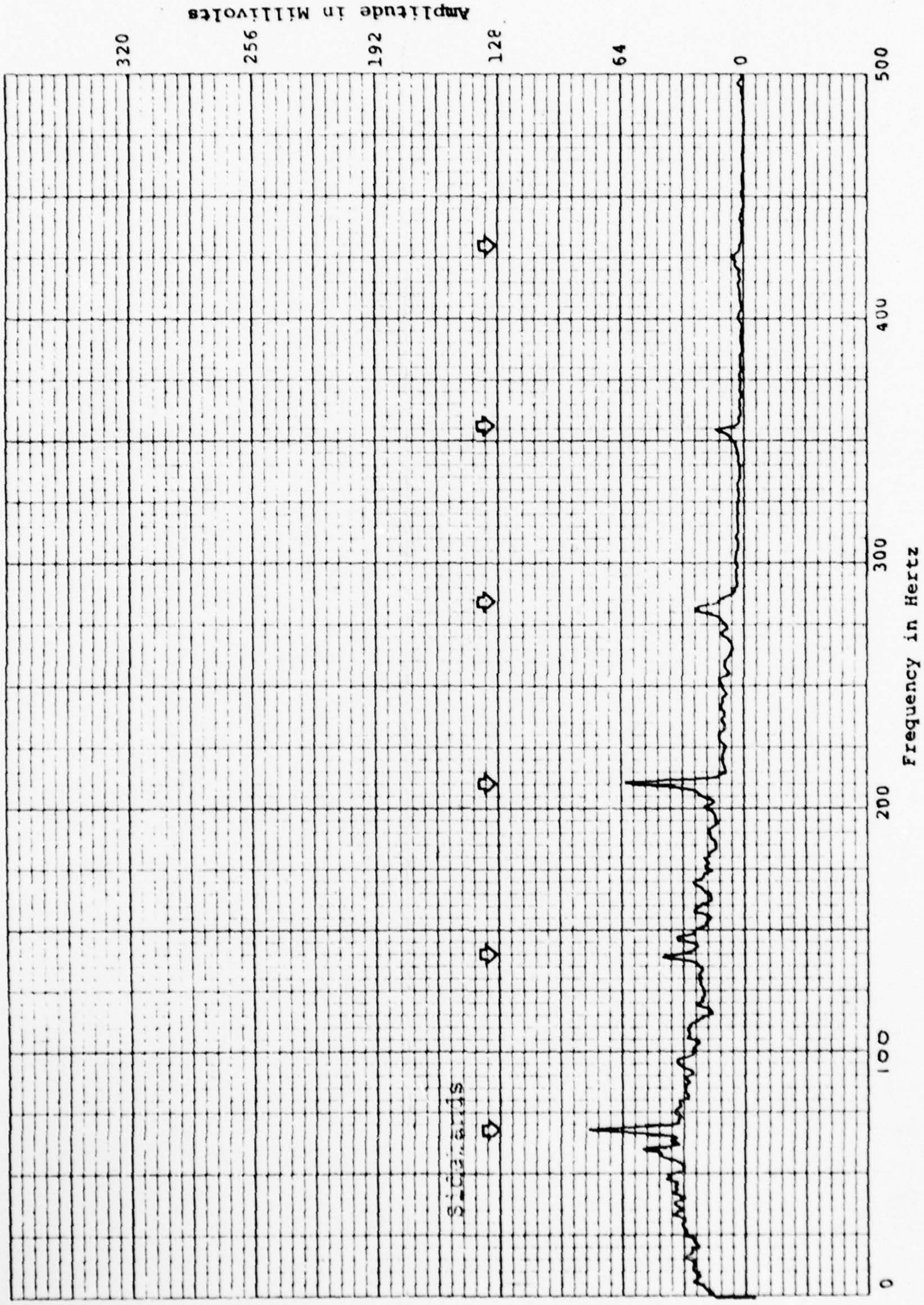

Figure B-23. Demodulated signal spectrum - 42° gearbox, t=90 hours

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APPENDIX C
UH-1H AND AH-1G FUNCTIONAL SYSTEMS PARAMETER ANALYSIS AND LOGIC DIAGRAMS

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TABLE OF CONTENTS

C-1.0 INTRODUCTION

This Appendix presents the fault logic diagrams for the major mechanical systems installed on the UH-1H and AH-1G helicopters. The diagrams isolate to the most probable failure mode and define the necessary inspection procedure and/or line replaceable unit (LRU) replacement. The information provided covers only one system where redundant systems are installed on the AH-1G, such as the dual hydraulic and the dual stability augmentation system. The UH-1H and AH-1G logic are shown on separate diagrams for clarity, even though in some cases the systems are identical.

C-2.0 LOGIC DIAGRAMS

C-2.1 UH-1H Logic Diagrams

The logic flow diagrams for the UH-1H subsystems are included in the figures noted as follows:

C-1 Engine Control and Lubrication
C-2 Transmission Lubrication
C-3 Engine Start and Battery
C-4 Main Generator
C-5 Standby Generator
C-6 AC Inverter
C-7 Fuel System
C-8 Hydraulic System
C-9 Speed Warning

C-2.2 AH-1G Logic Diagrams

The logic flow diagrams for the AH-1G subsystems are included in the figures noted as follows:

C-10 Engine Control and Lubrication
C-11 Transmission Lubrication
C-12 Fuel System
C-13 Engine Start and Battery
C-14 Main Generator
C-15 AC Inverter
C-16 No. 2 Hydraulic System
C-17 SAS Pitch Channel
C-18 Gun Turret Position
C-19 Environmental Control Unit (ECU)
C-20 Speed Warning

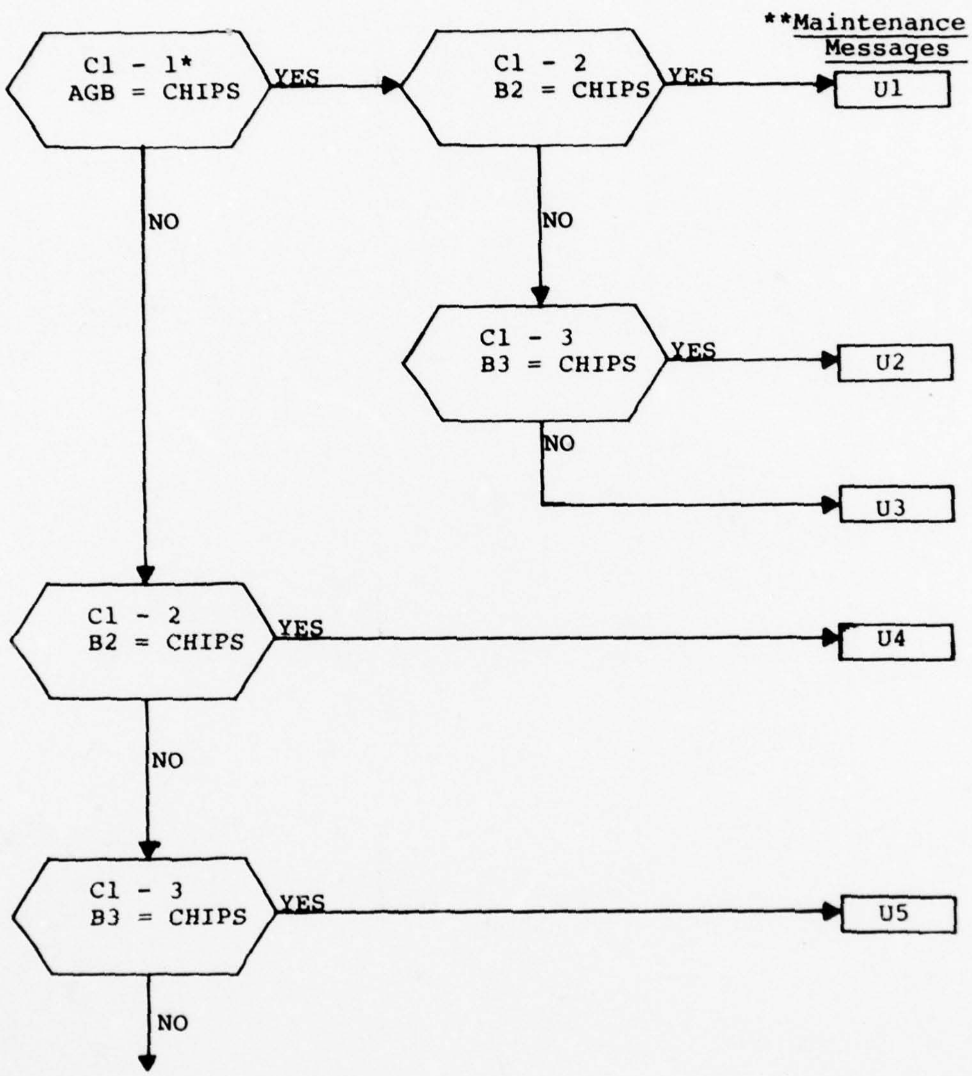
C-3.0 TEST POINTS AND PARAMETERS

Each monitored parameter has been symbolized and assigned a test point on the logic diagram for ease of identification and communications. Tables C-I and C-II identify the parameter symbols, the test points, and the availability of sensors to detect the associated parameters. The requirement for new sensors in

addition to those available on the aircraft or proposed by the AIDAPS hardware developer were kept to a minimum. To adequately monitor some systems, however, new sensors or taps from existing sensors are required.

C-4.0 MAINTENANCE MESSAGES

System failures or maintenance instructions are identified on the logic diagrams by maintenance message numbers. Tables C-III and C-IV list the UH-1H and AH-1G message numbers in sequence with the associated messages describing the required maintenance actions. In cases where the messages indicate an inspection requirement or choice of LRU replacements, the appropriate Technical Manual troubleshooting or inspection procedures are to be used for final fault isolation.



*See Table C-1
**See Table C-3

Figure C-1. UH-1H engine control and lubrication logic.

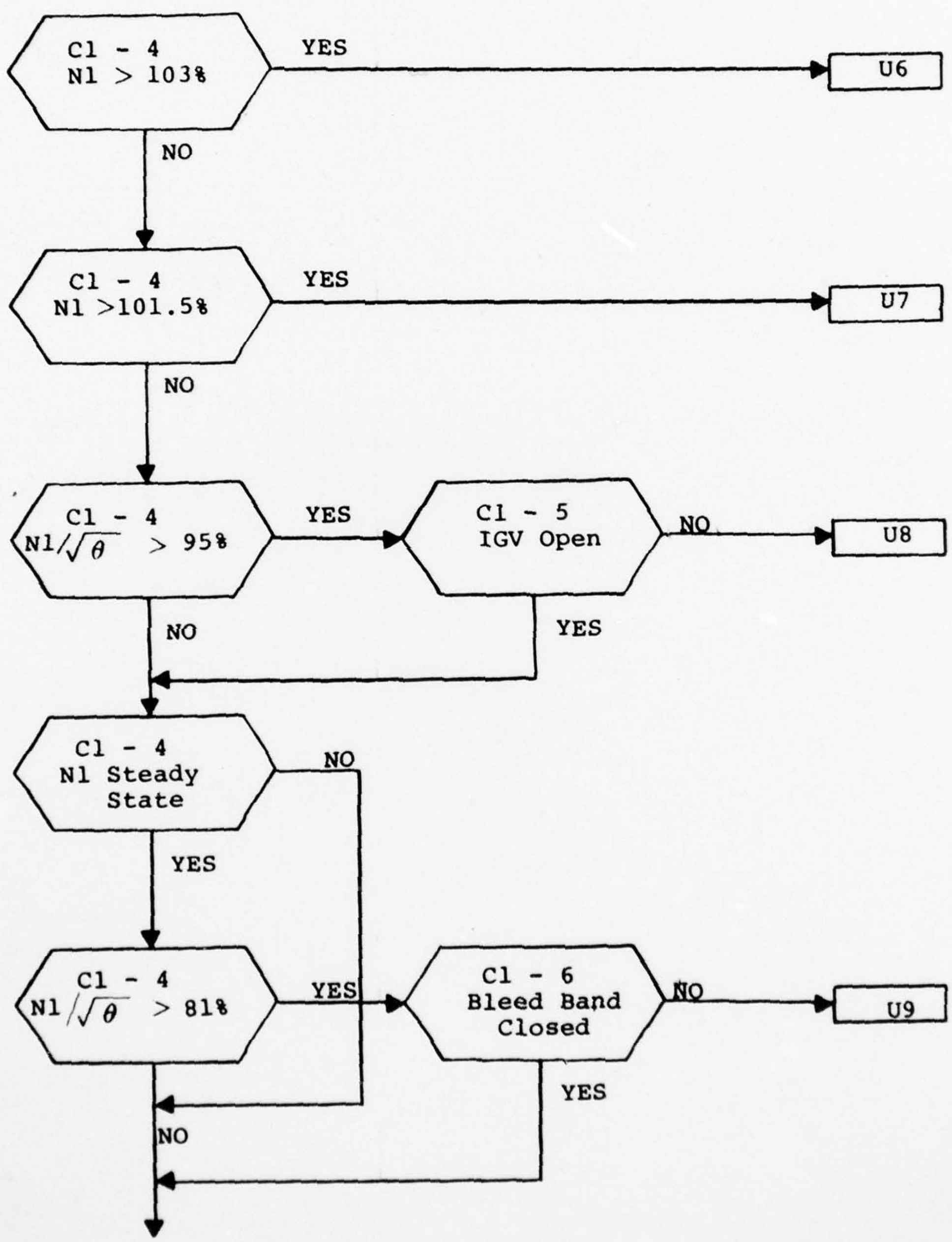


Figure C-1. (Continued)

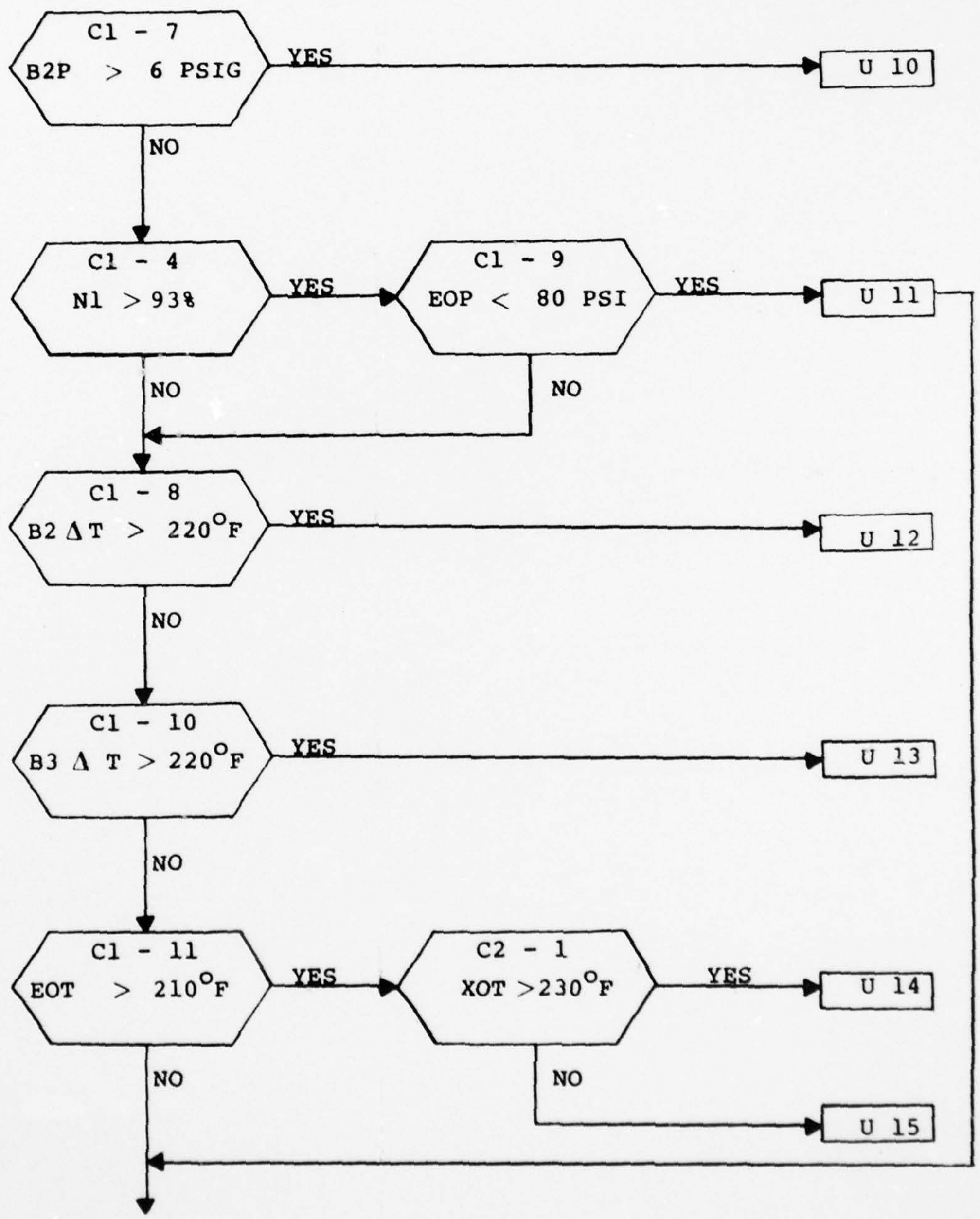


Figure C-1. (Continued)

AD-A055 385 BELL HELICOPTER TEXTRON FORT WORTH TEX F/G 14/2
AUTOMATIC INSPECTION, DIAGNOSTIC AND PROGNOSTIC SYSTEM (AIDAPS)--ETC(U)
AUG 77 . J V HICKEY DAAJ01-71-A-0335

UNCLASSIFIED USAAVRADCOM-TR-78-4 NL

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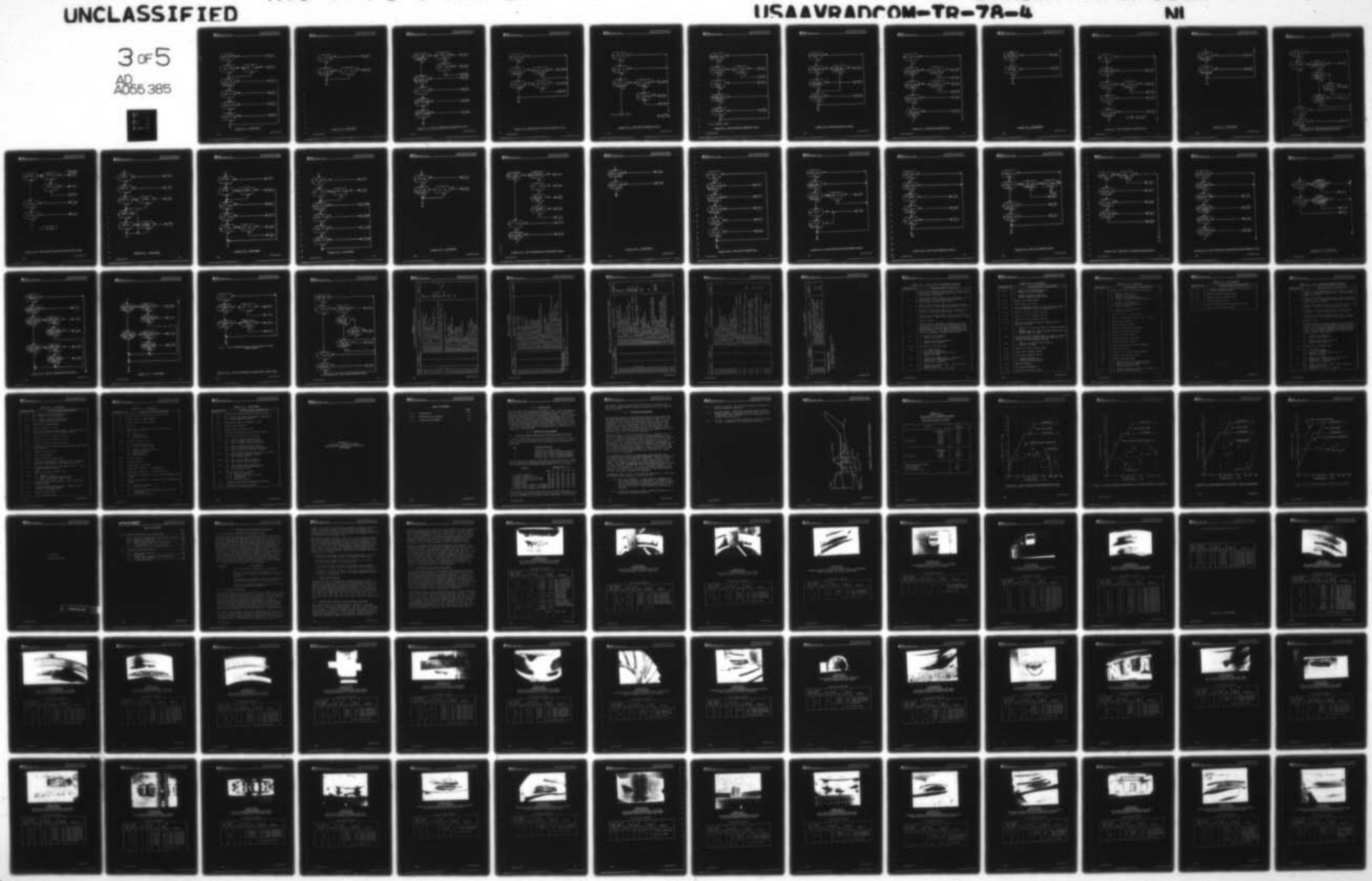

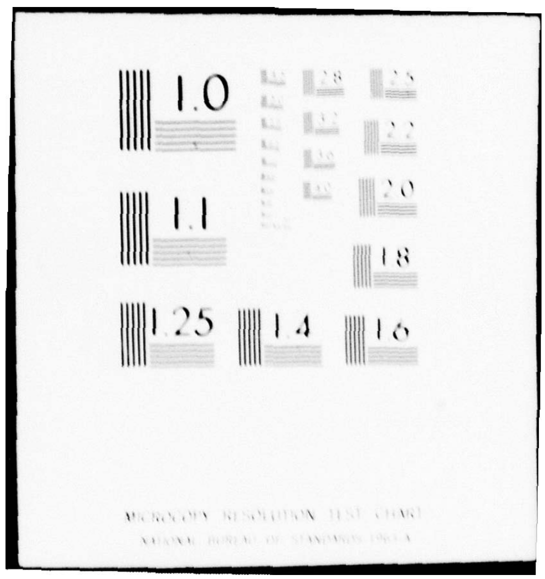
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

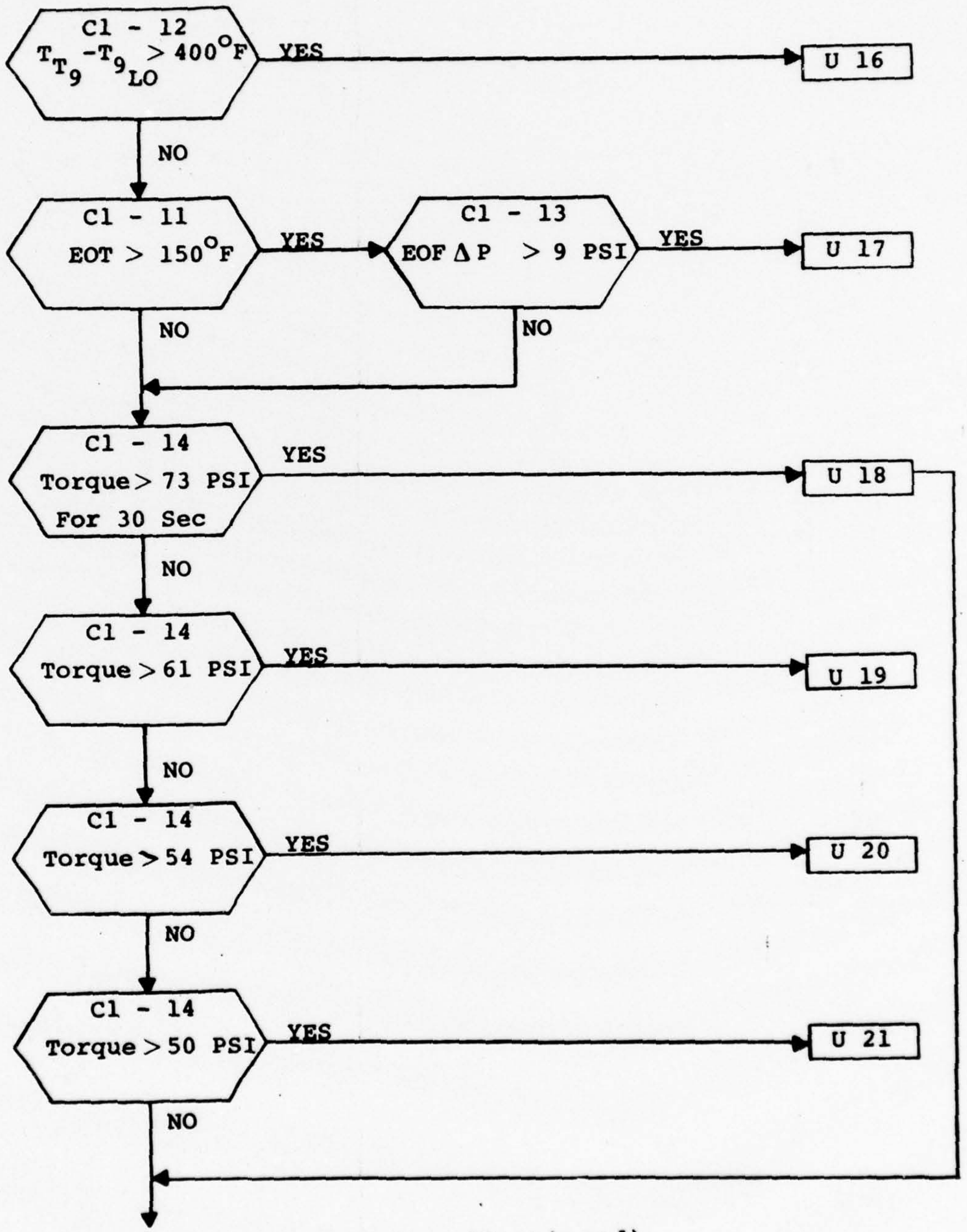
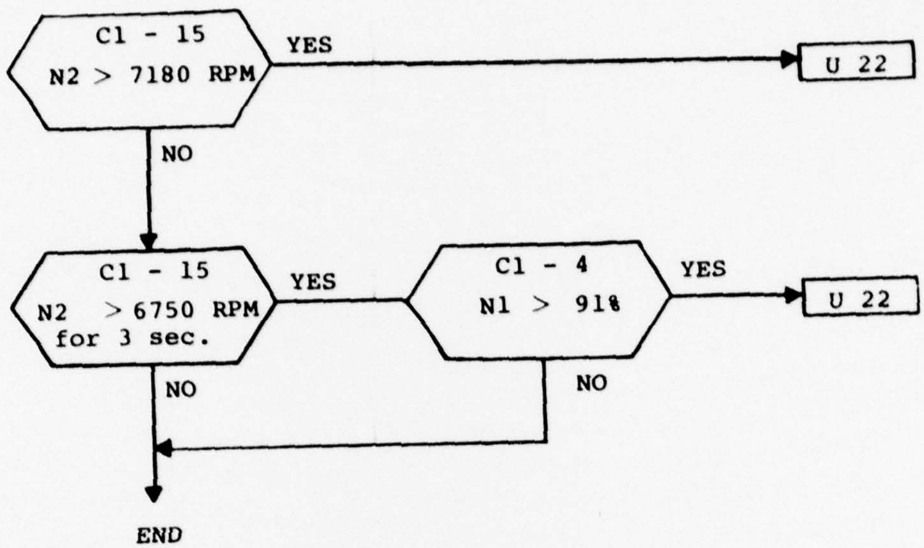


Figure C-1. (Continued)



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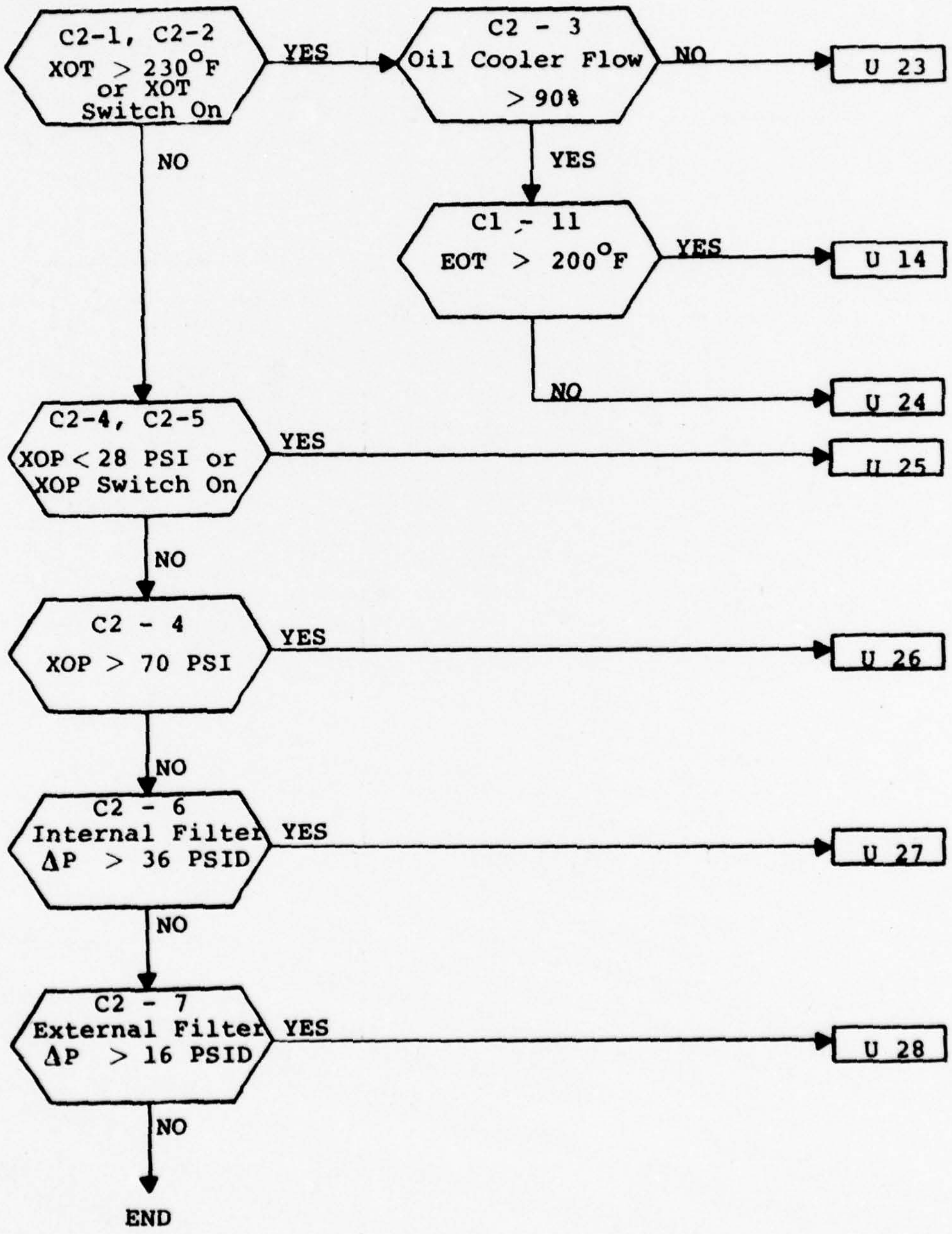


Figure C-2. UH-1H transmission lubrication logic.

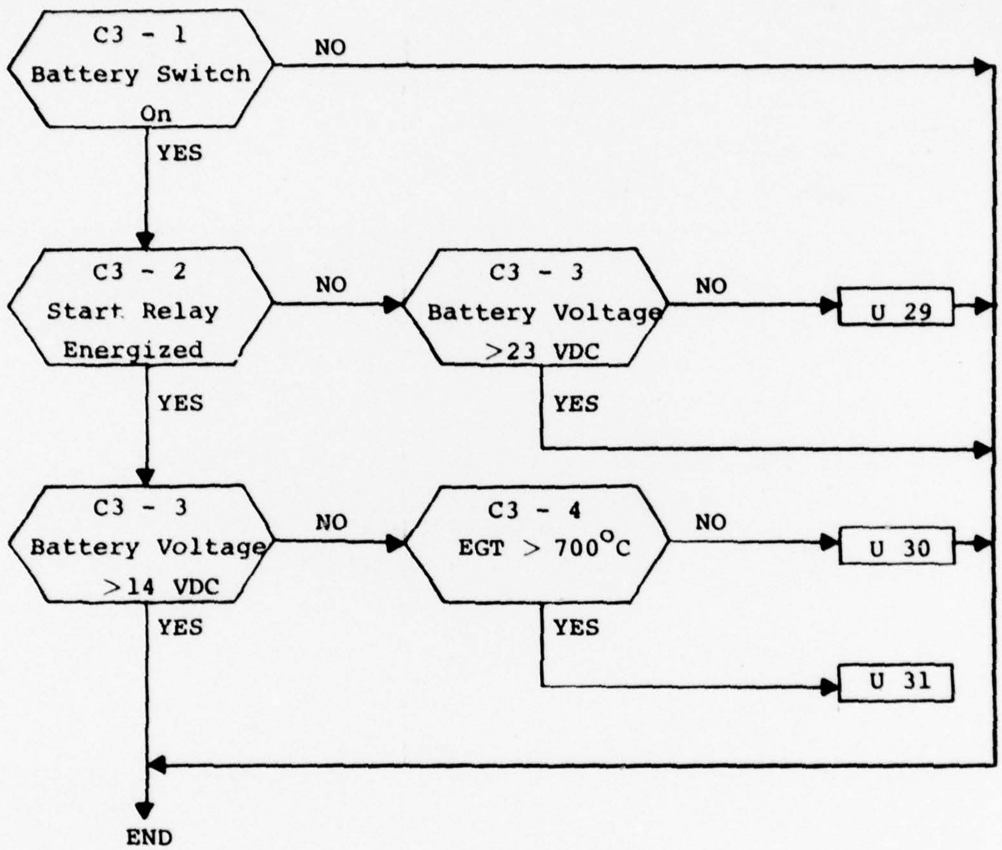


Figure C-3. UH-1H engine start and battery logic.

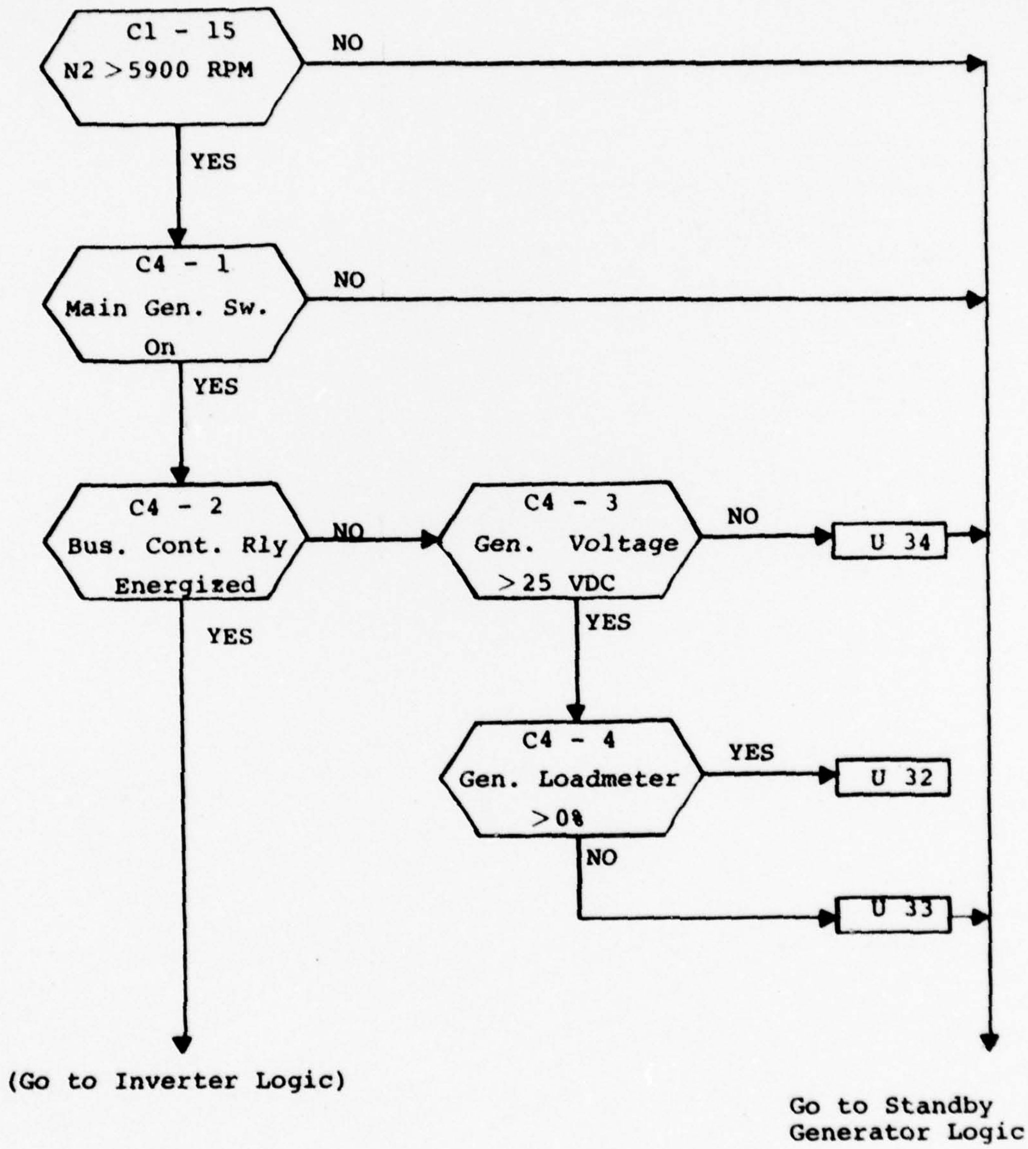


Figure C-4. UH-1H main generator logic.

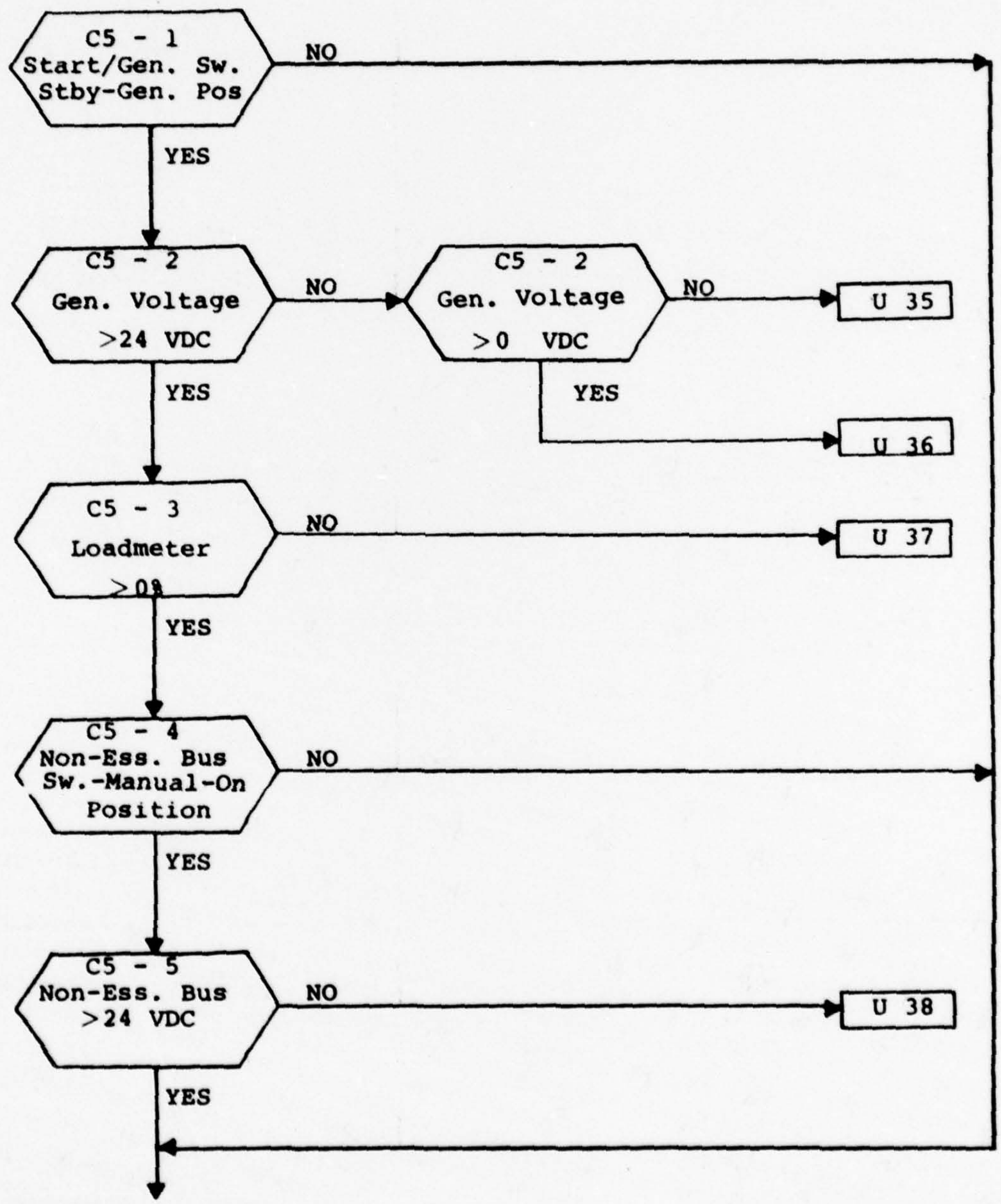


Figure C-5. UH-1H stand-by generator logic.

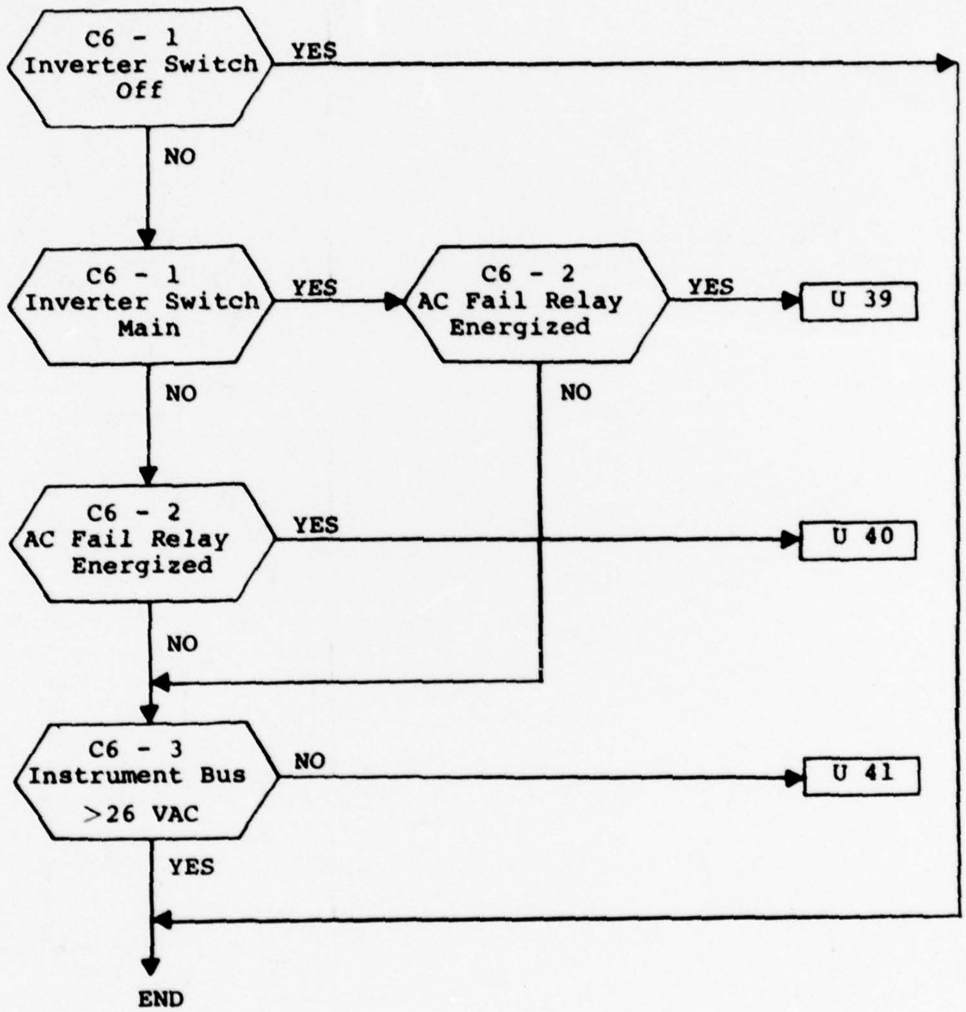


Figure C-6. UH-1H AC inverter logic.

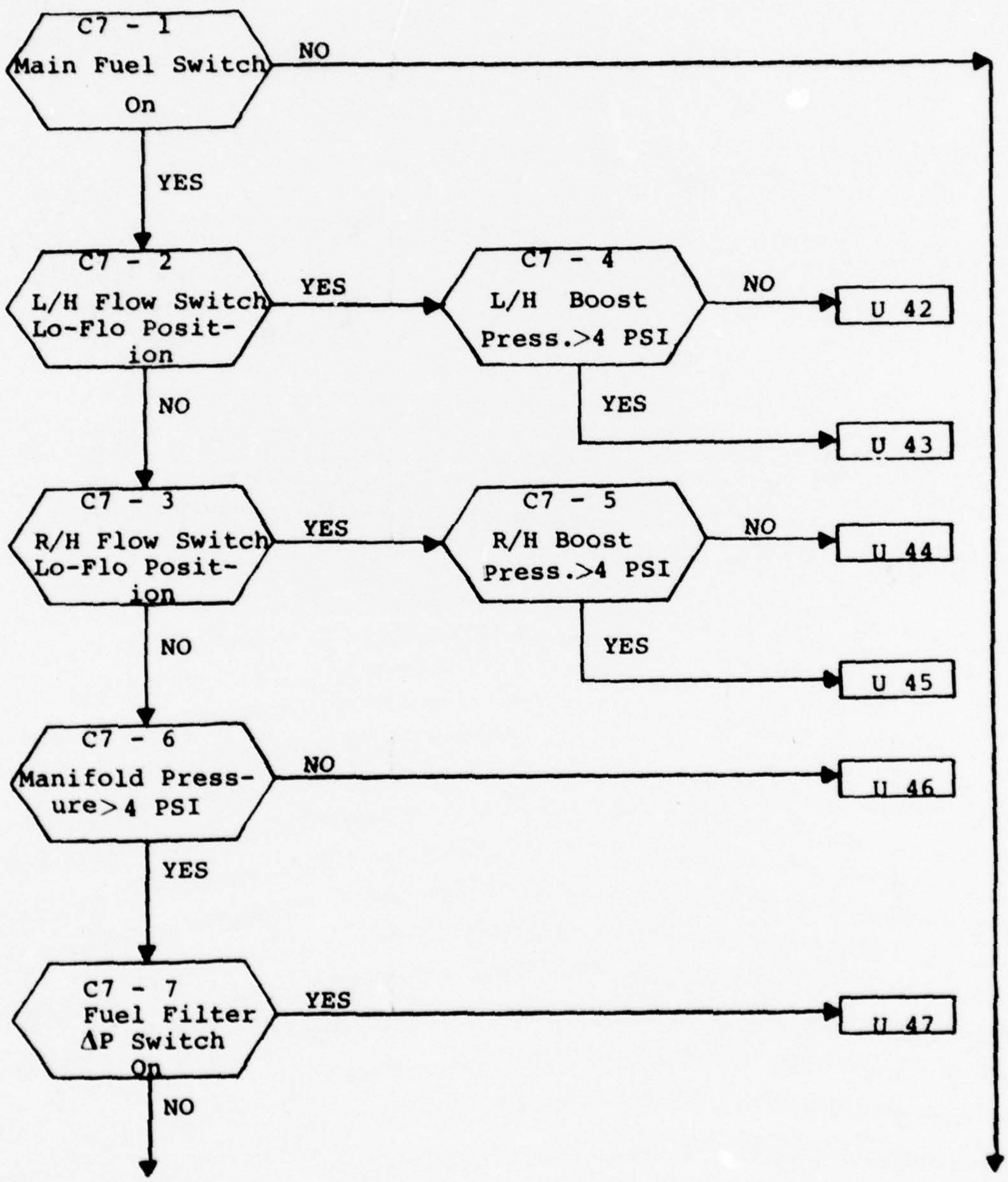
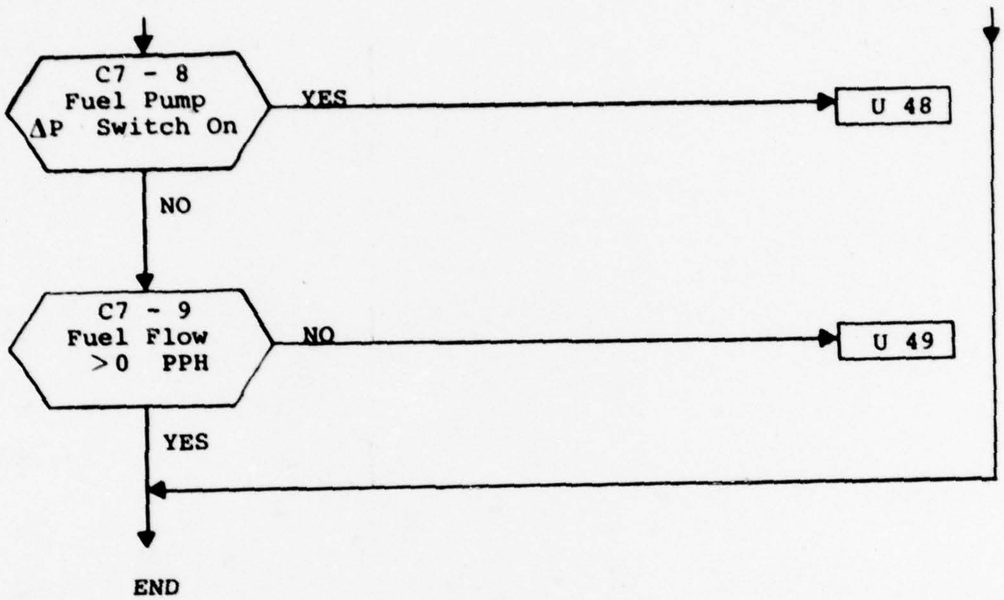


Figure C-7. UH-1H fuel system logic.



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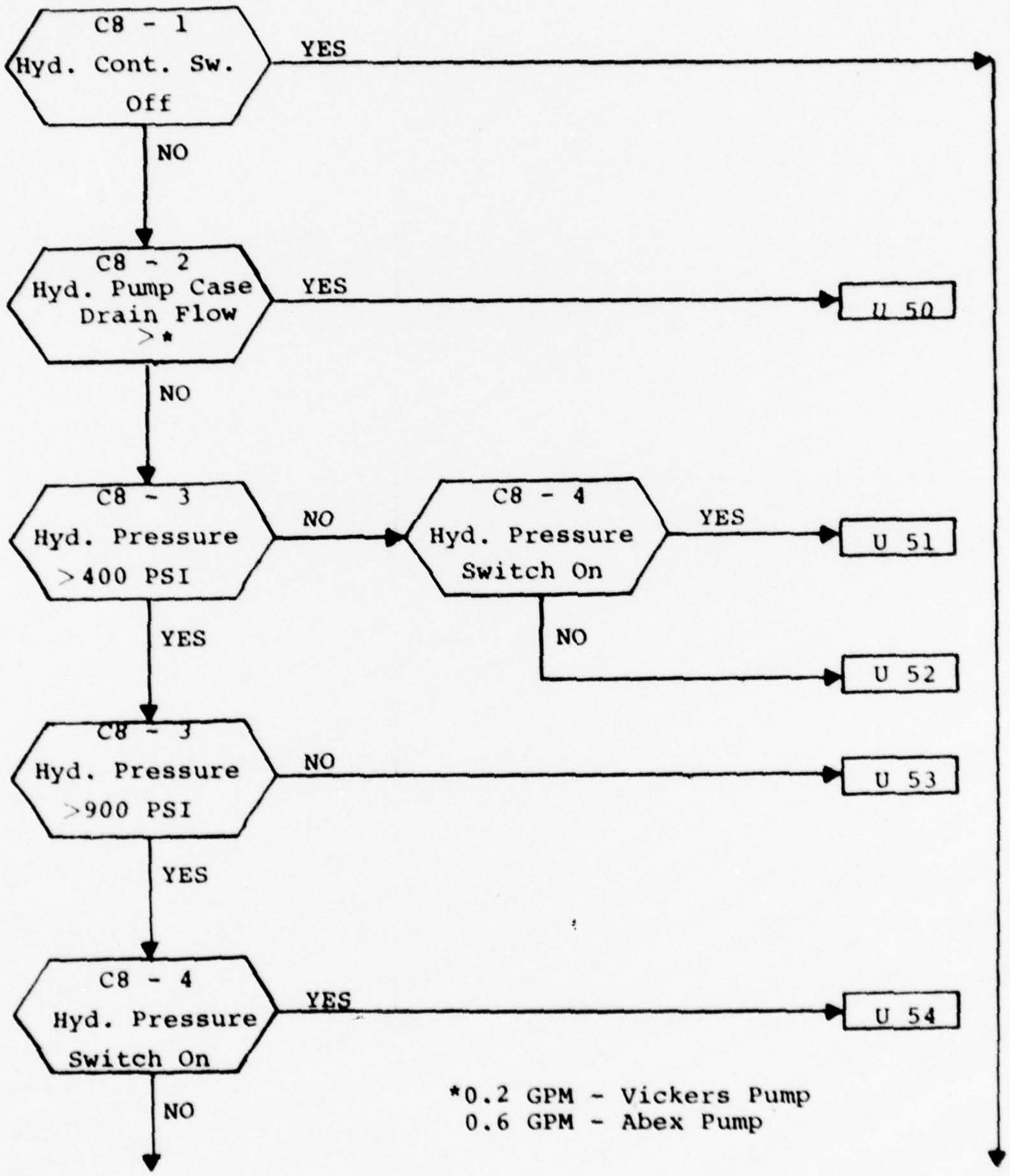
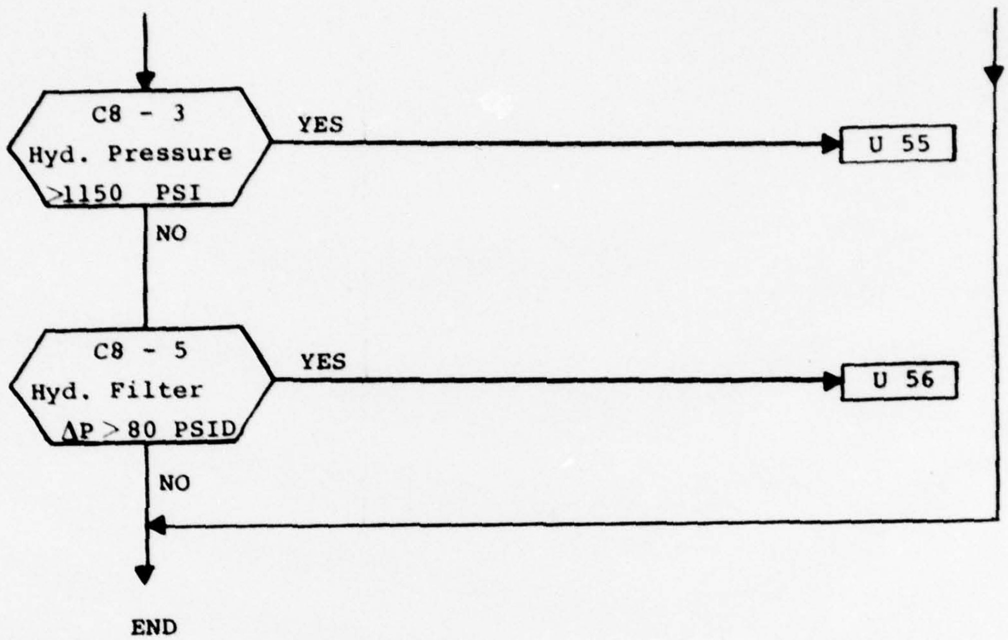


Figure C-8. UH-1H hydraulic system logic.



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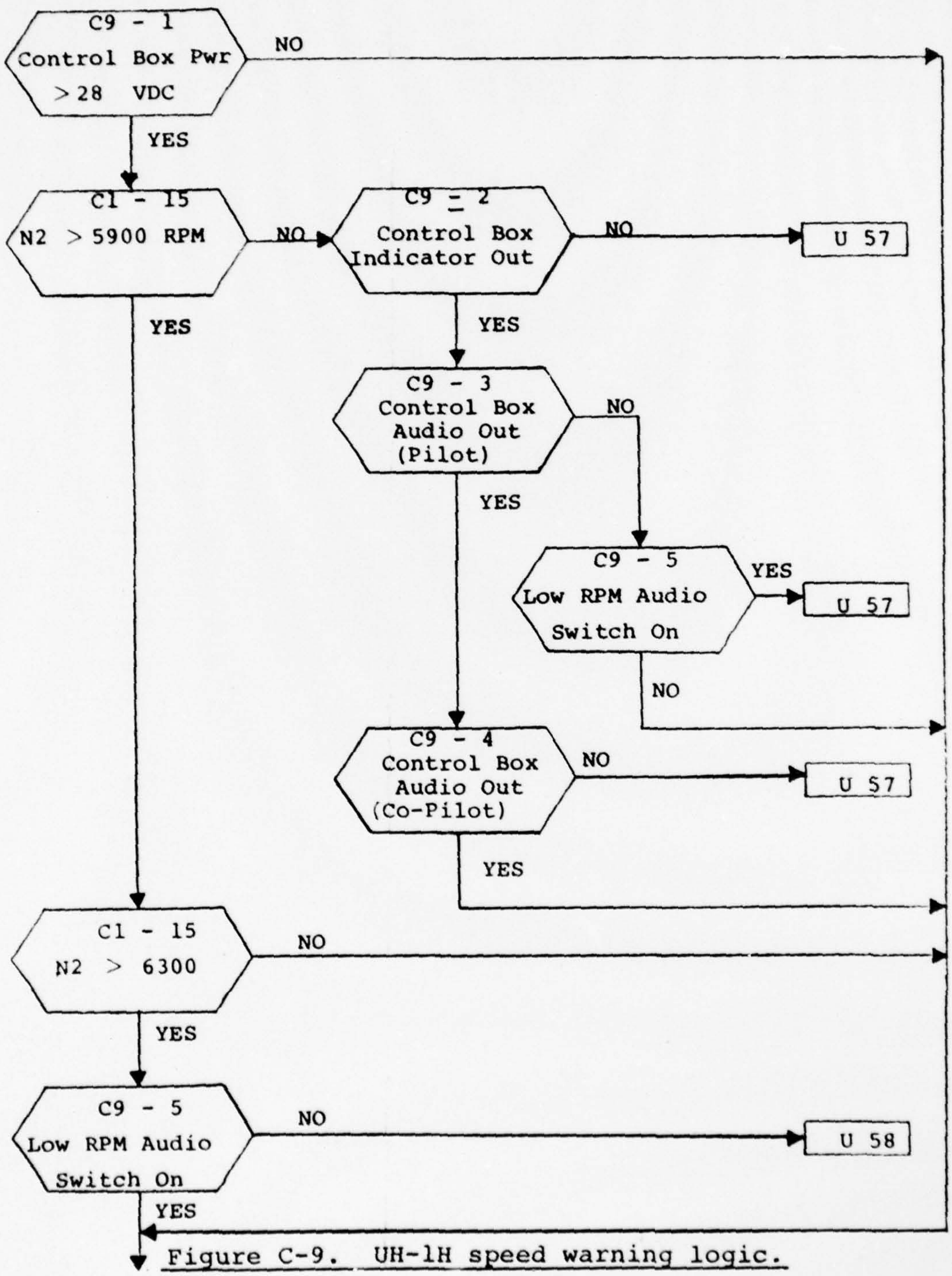

Figure C-9. UH-1H speed warning logic.

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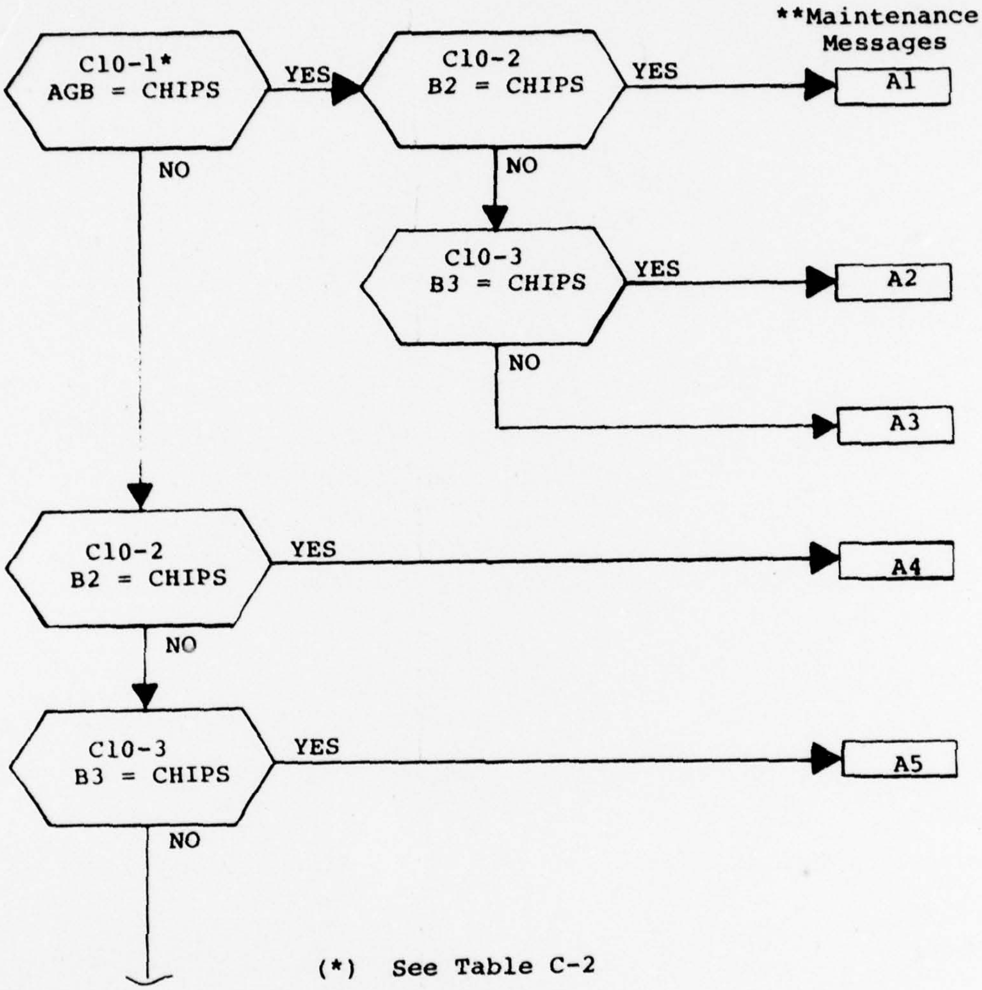
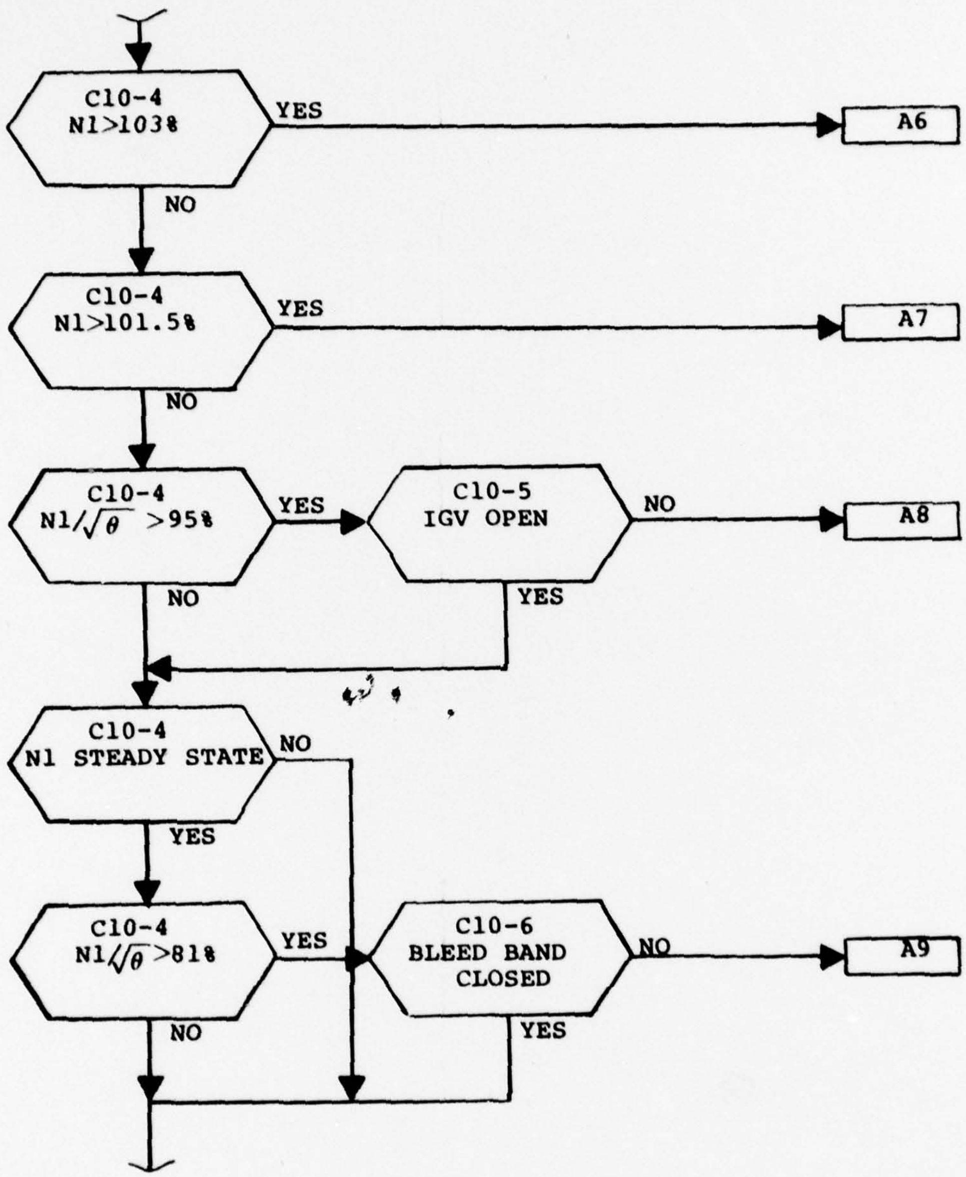


(*) See Table C-2

(**) See Table C-4

Figure C-10. AH-1G engine control and lubrication logic.



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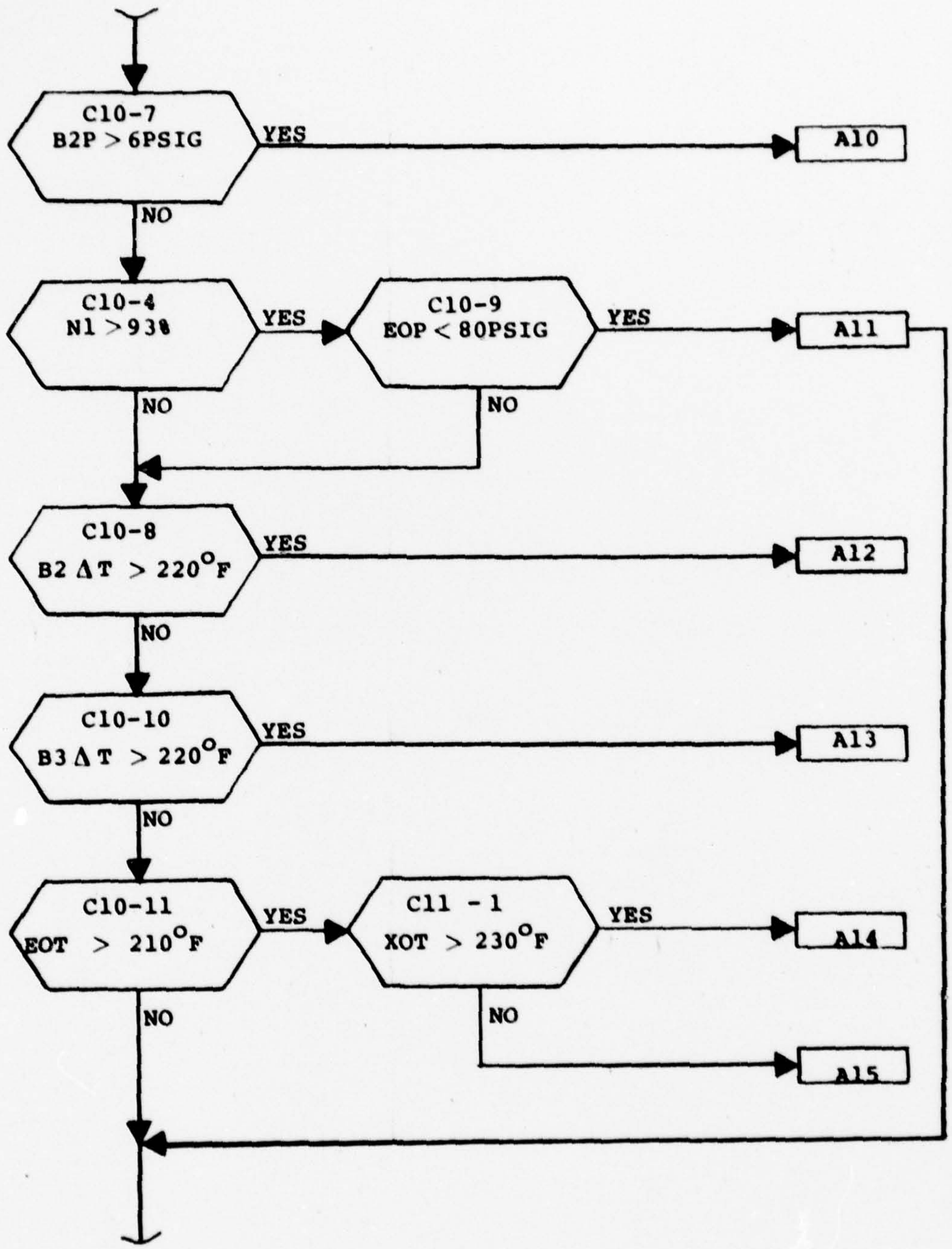

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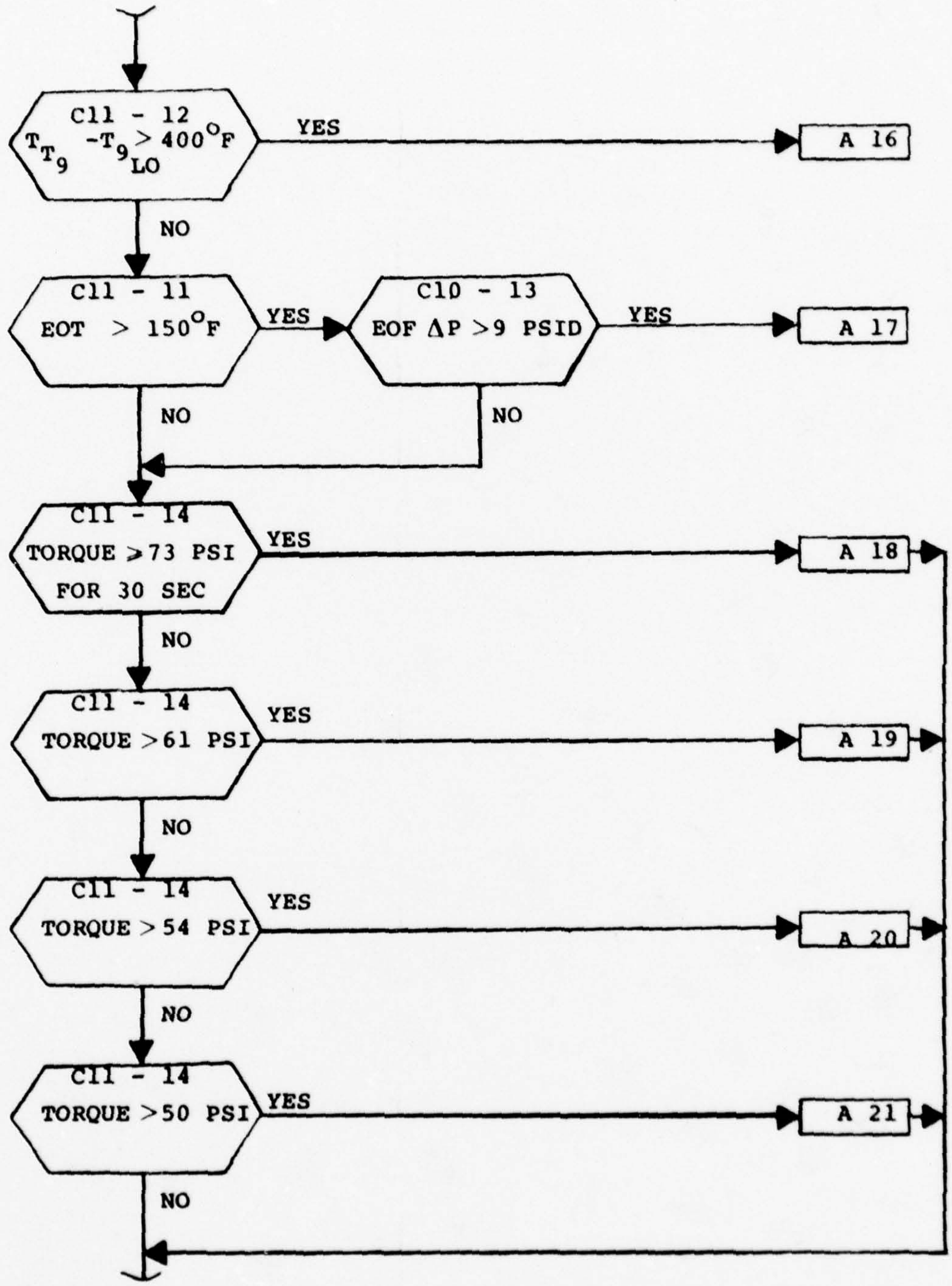

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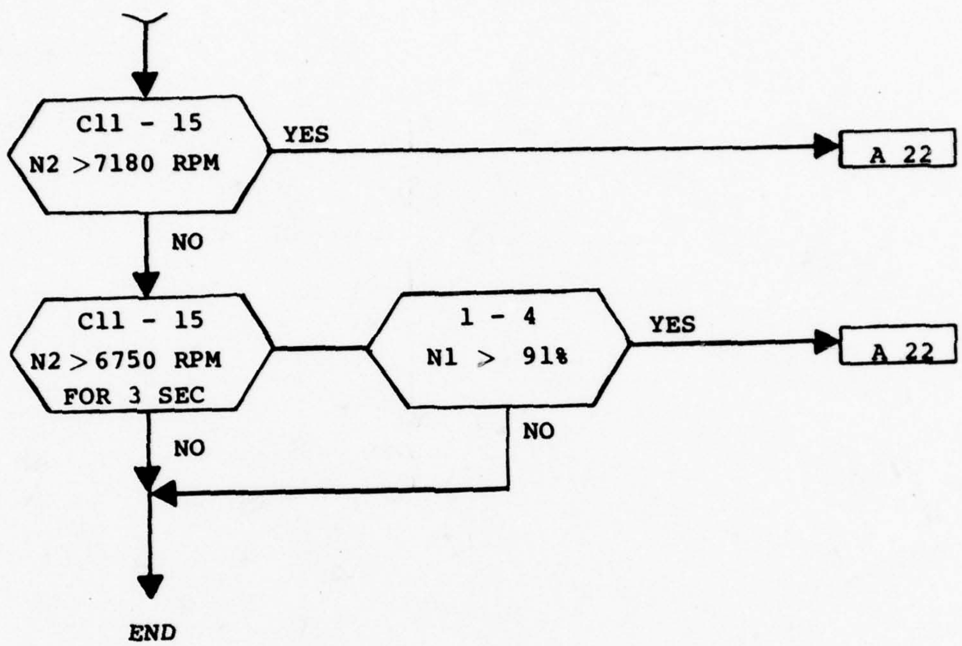

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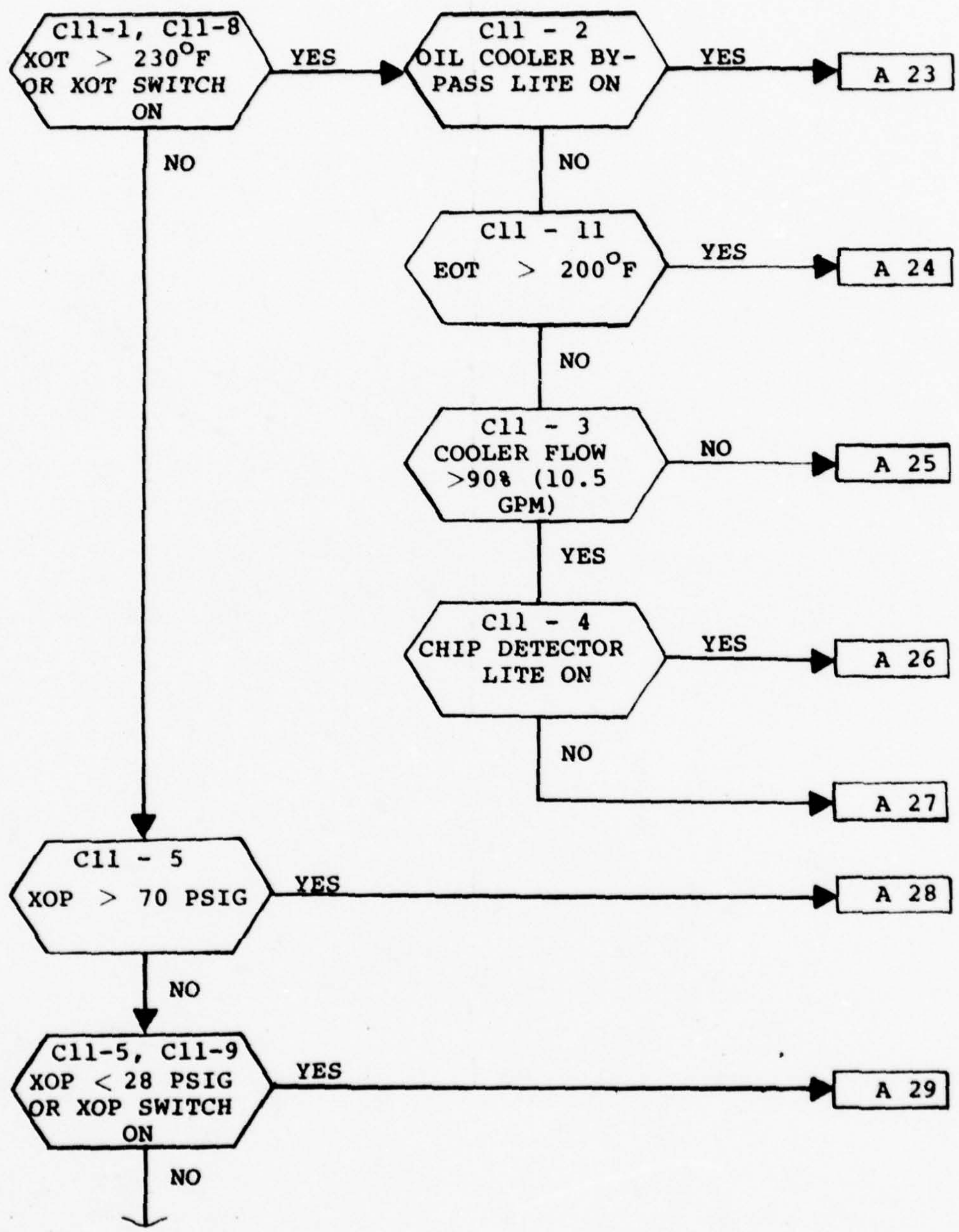

Figure C-11. AH-1G transmission lubrication logic.

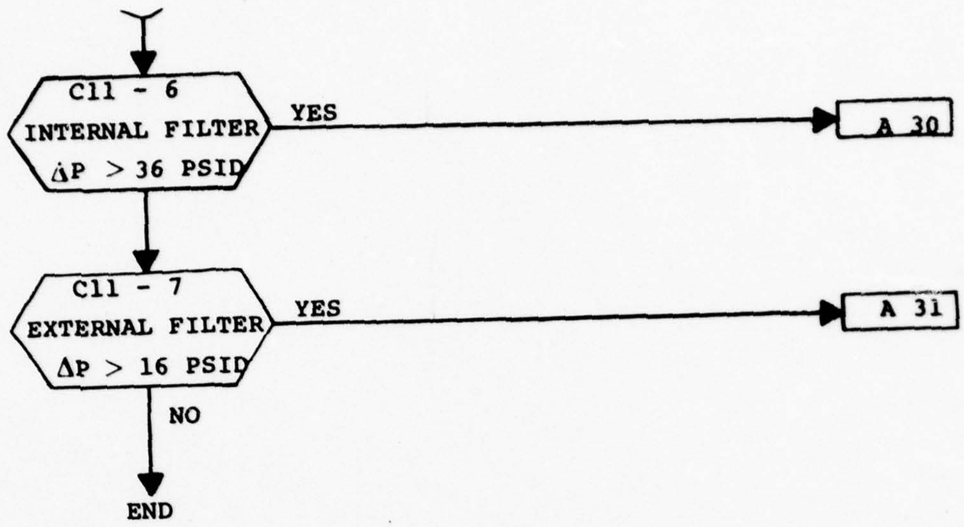

Figure C-11. (Concluded)

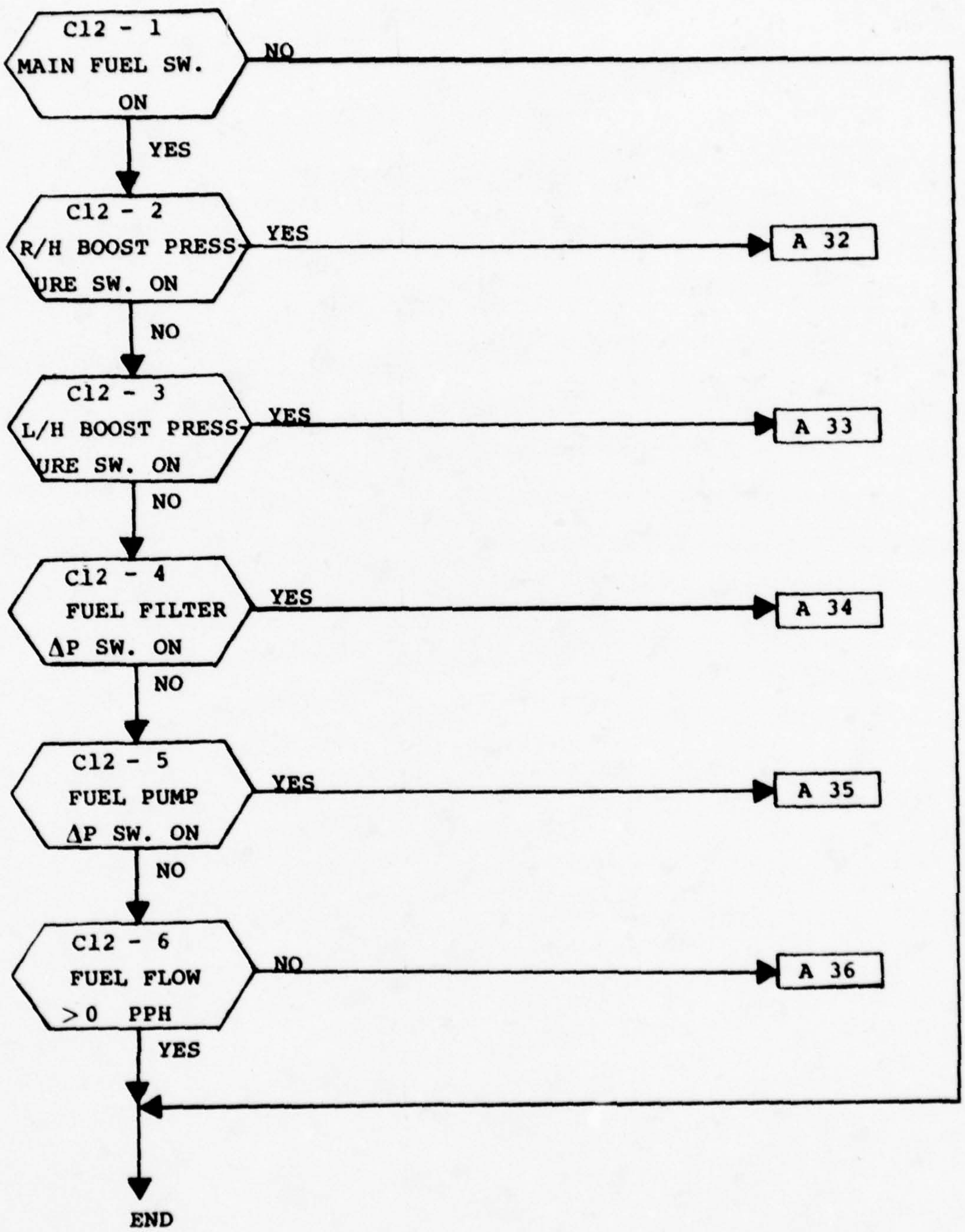

Figure C-12. AH-1G fuel system logic.

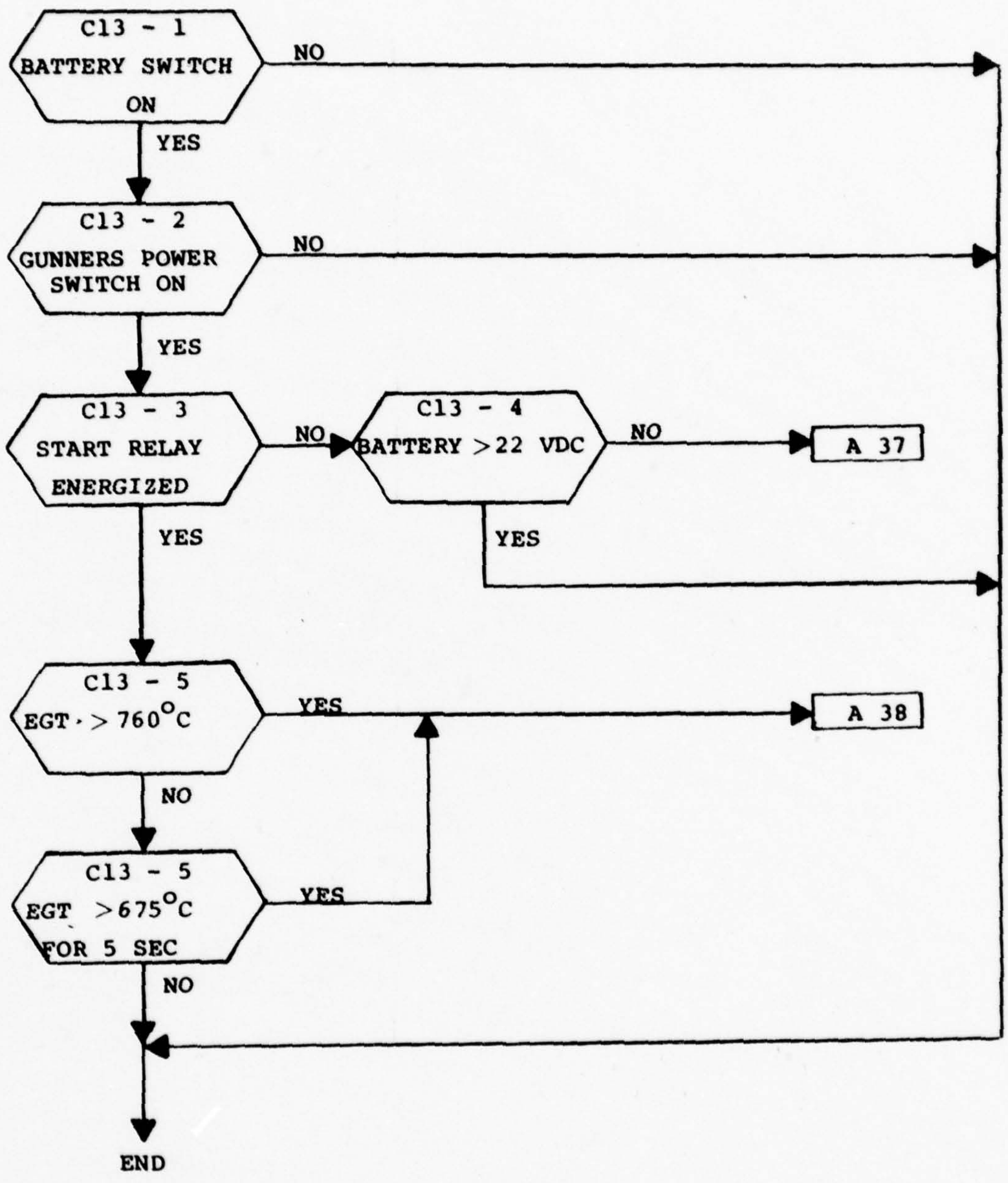

Figure C-13. AH-1G engine start and battery logic.

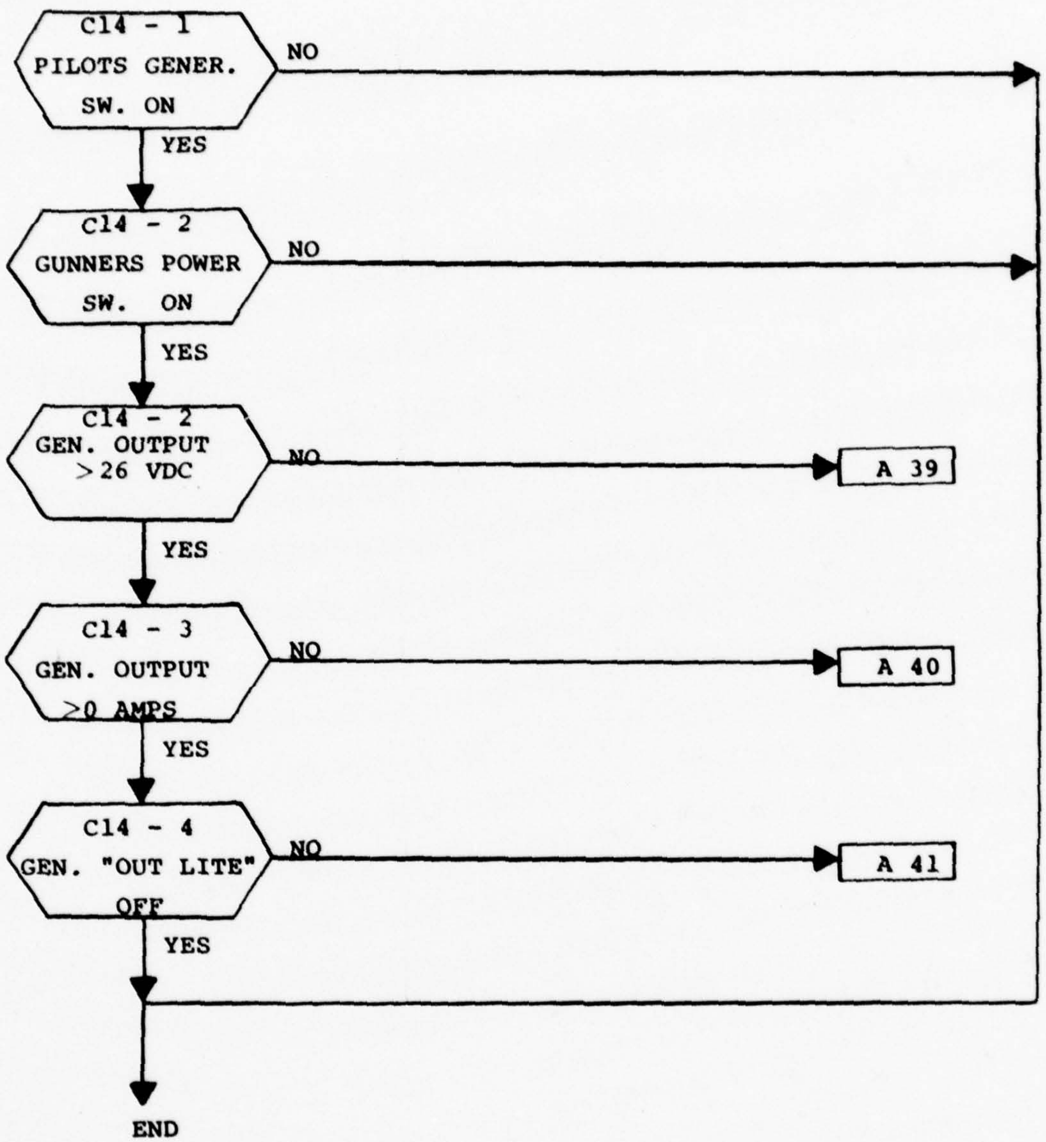

Figure C-14. AH-1G main generator logic.

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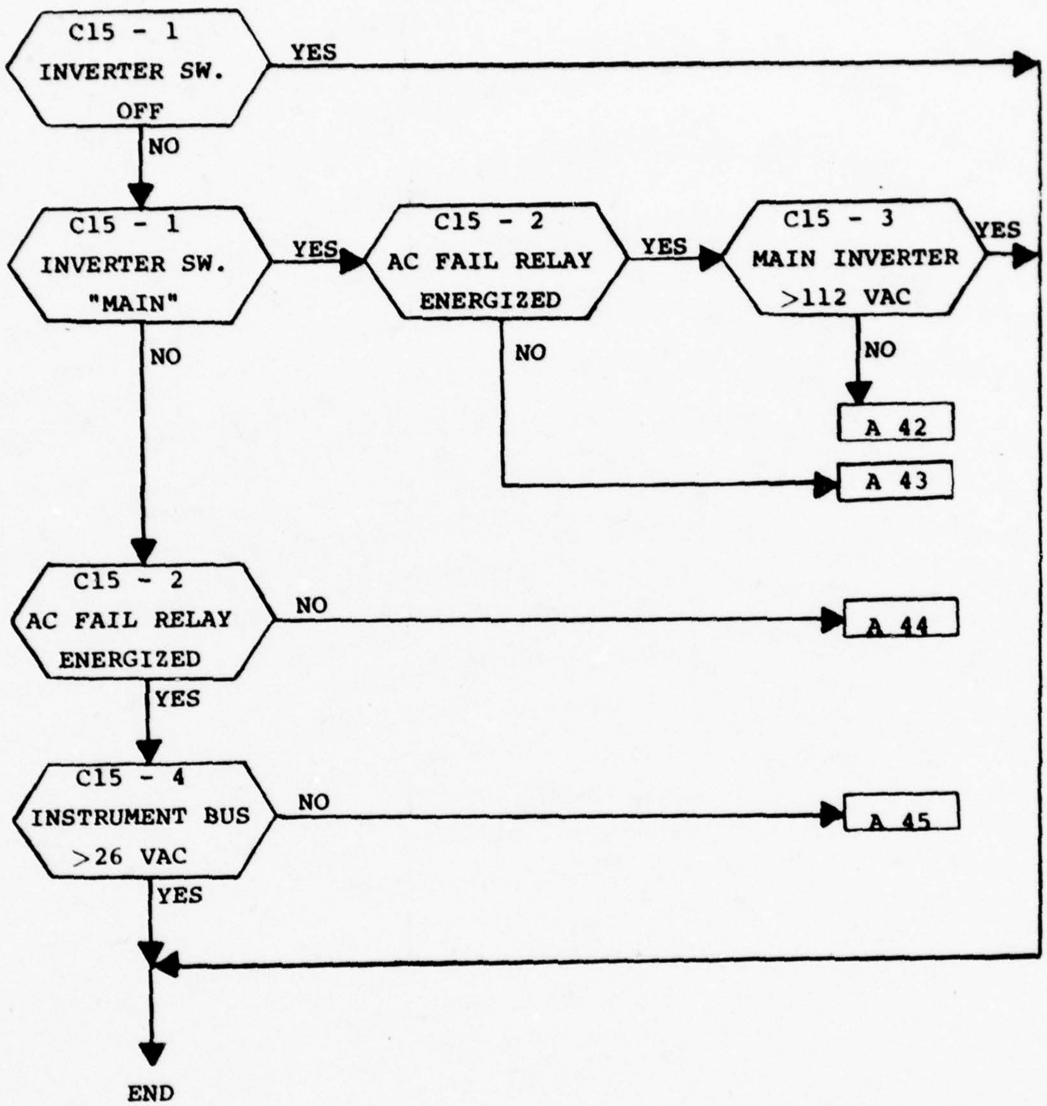


Figure C-15. AH-1G AC inverter logic.

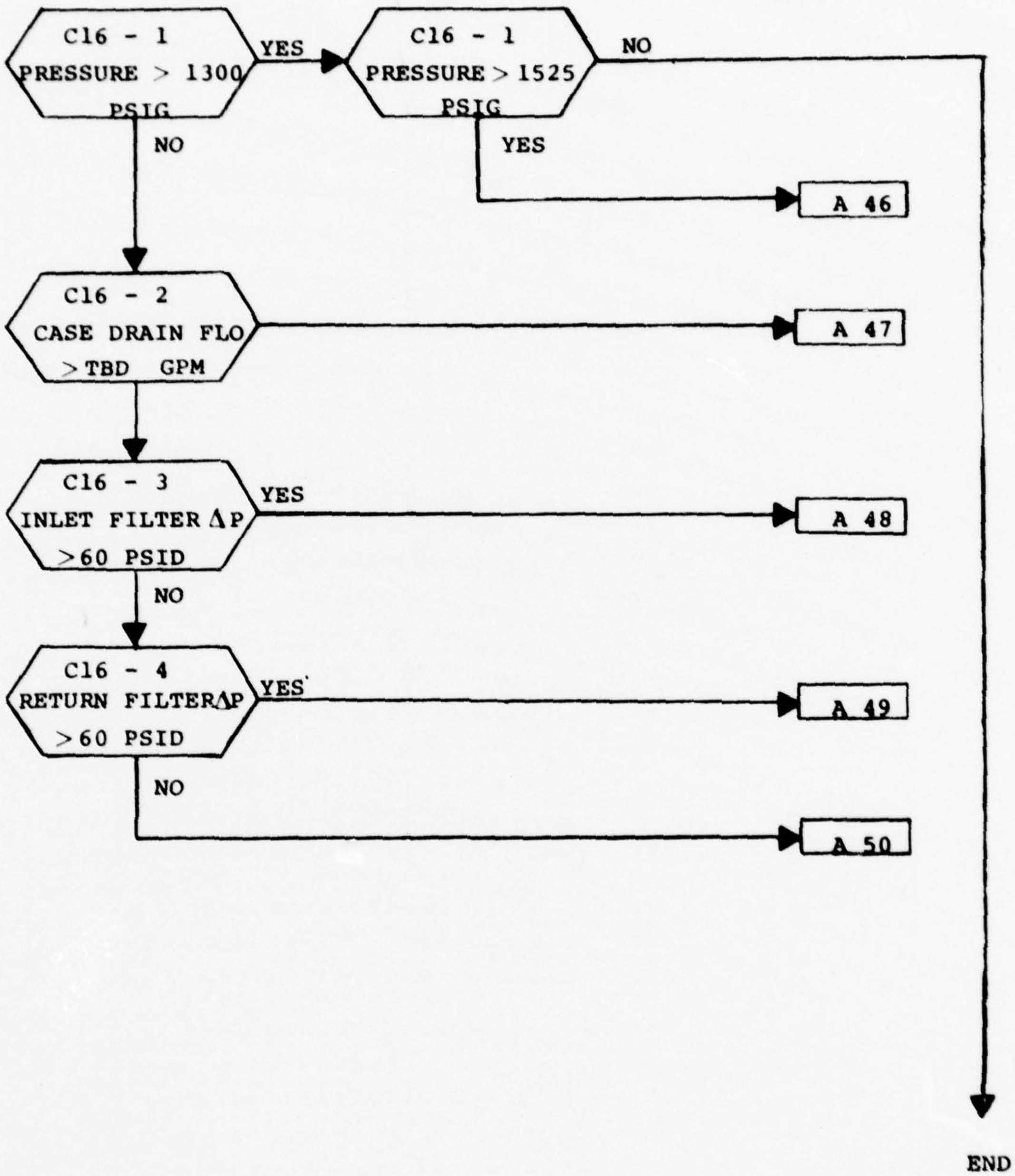


Figure C-16. AH-1G No. 2 hydraulic system logic.

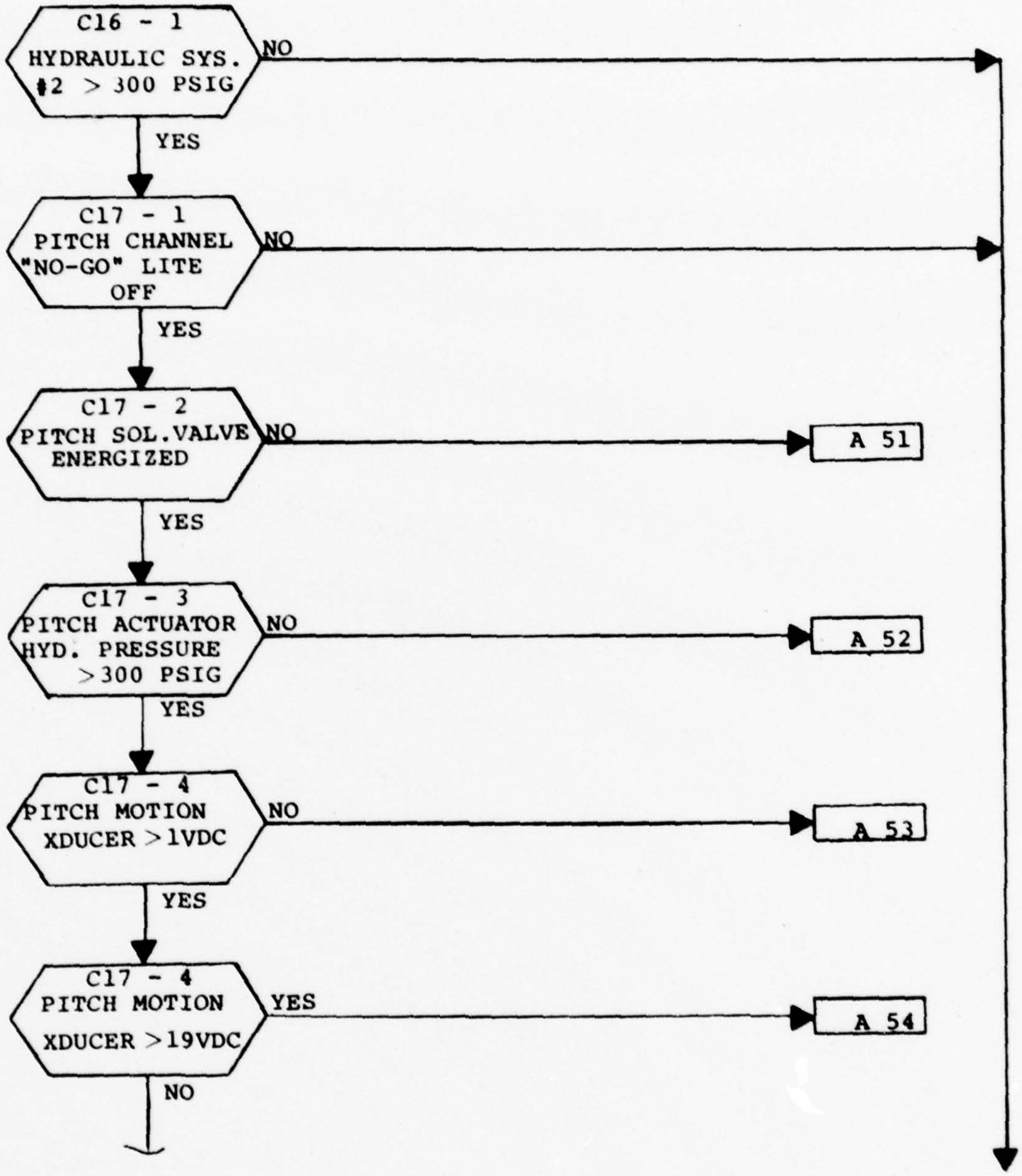
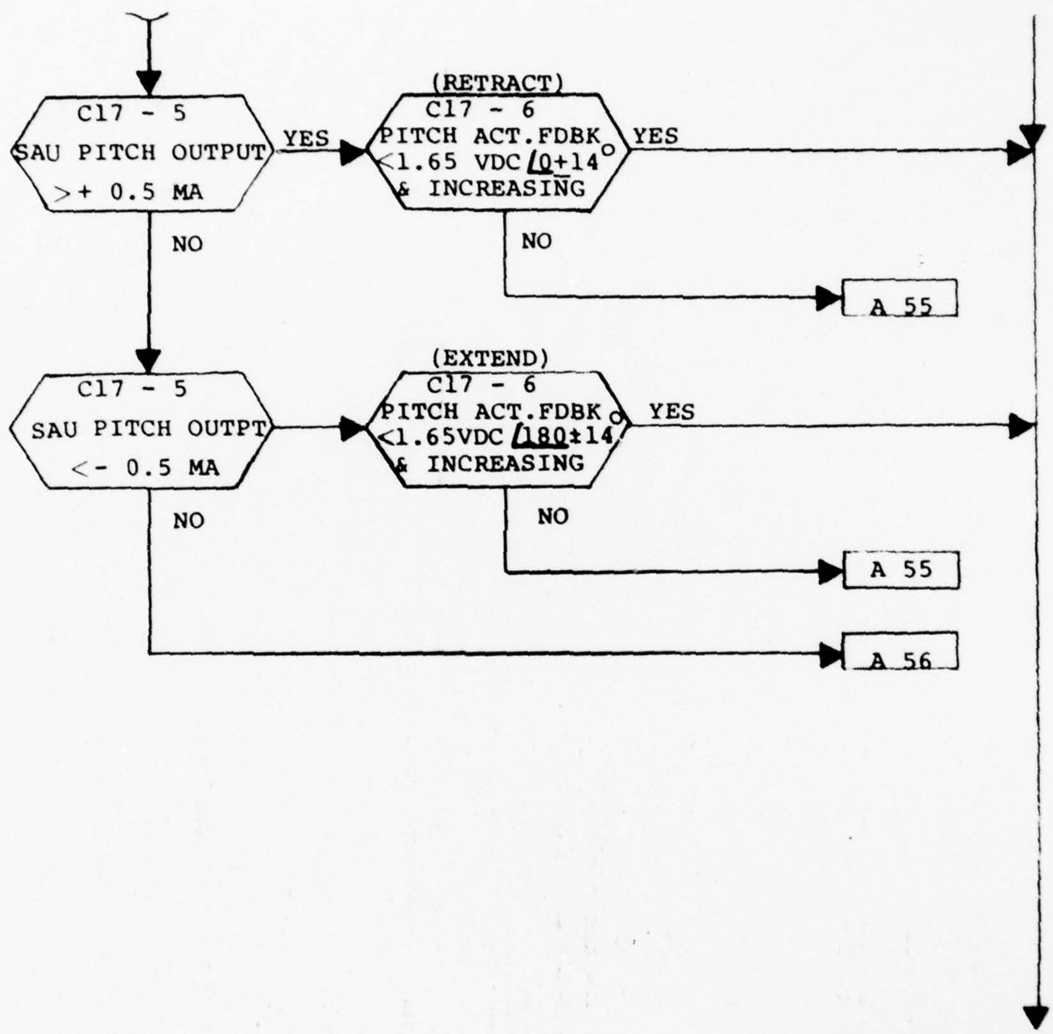


Figure C-17. AH-1G stability augmentation (pitch channel) logic.



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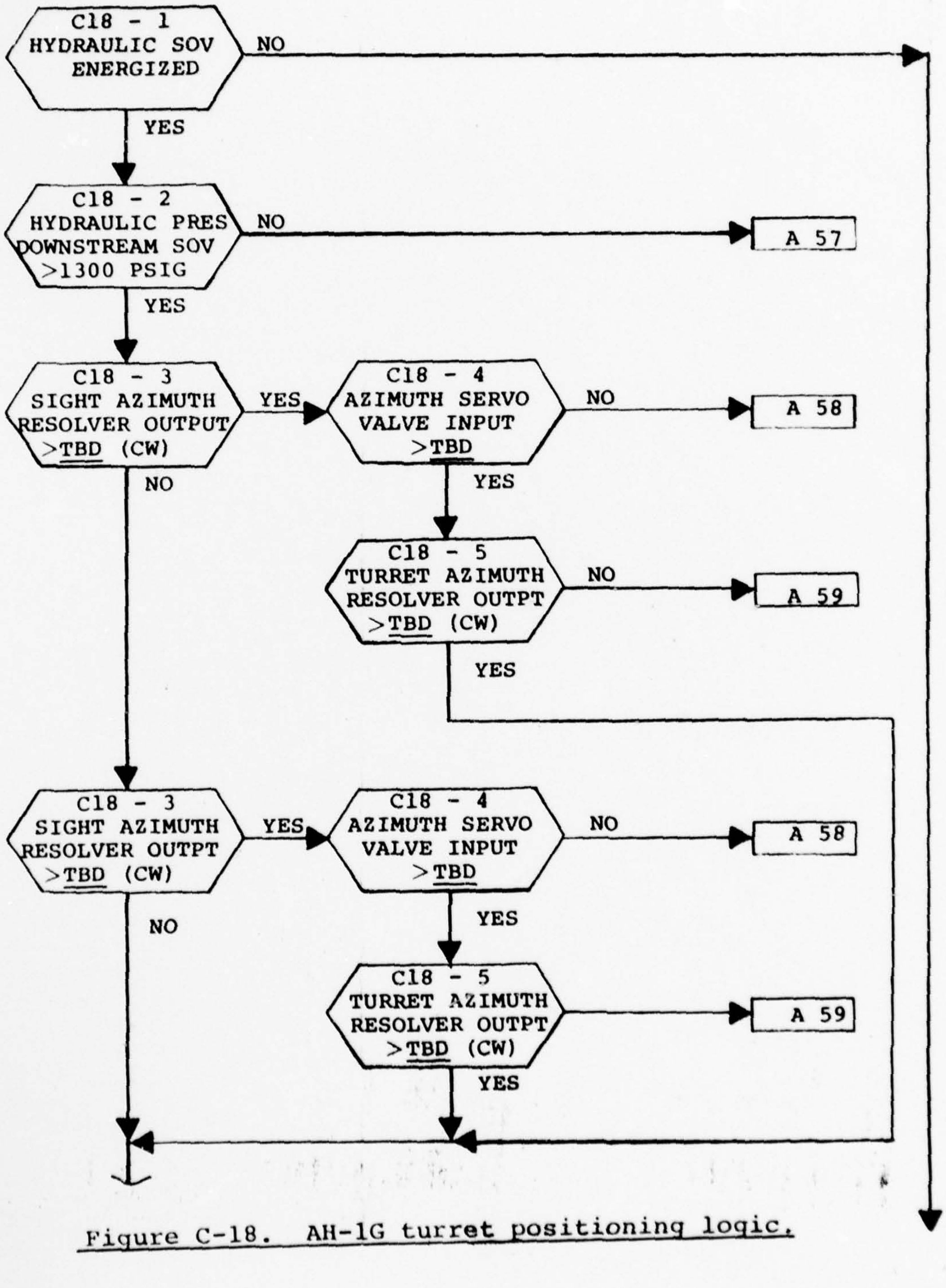

Figure C-18. AH-1G turret positioning logic.

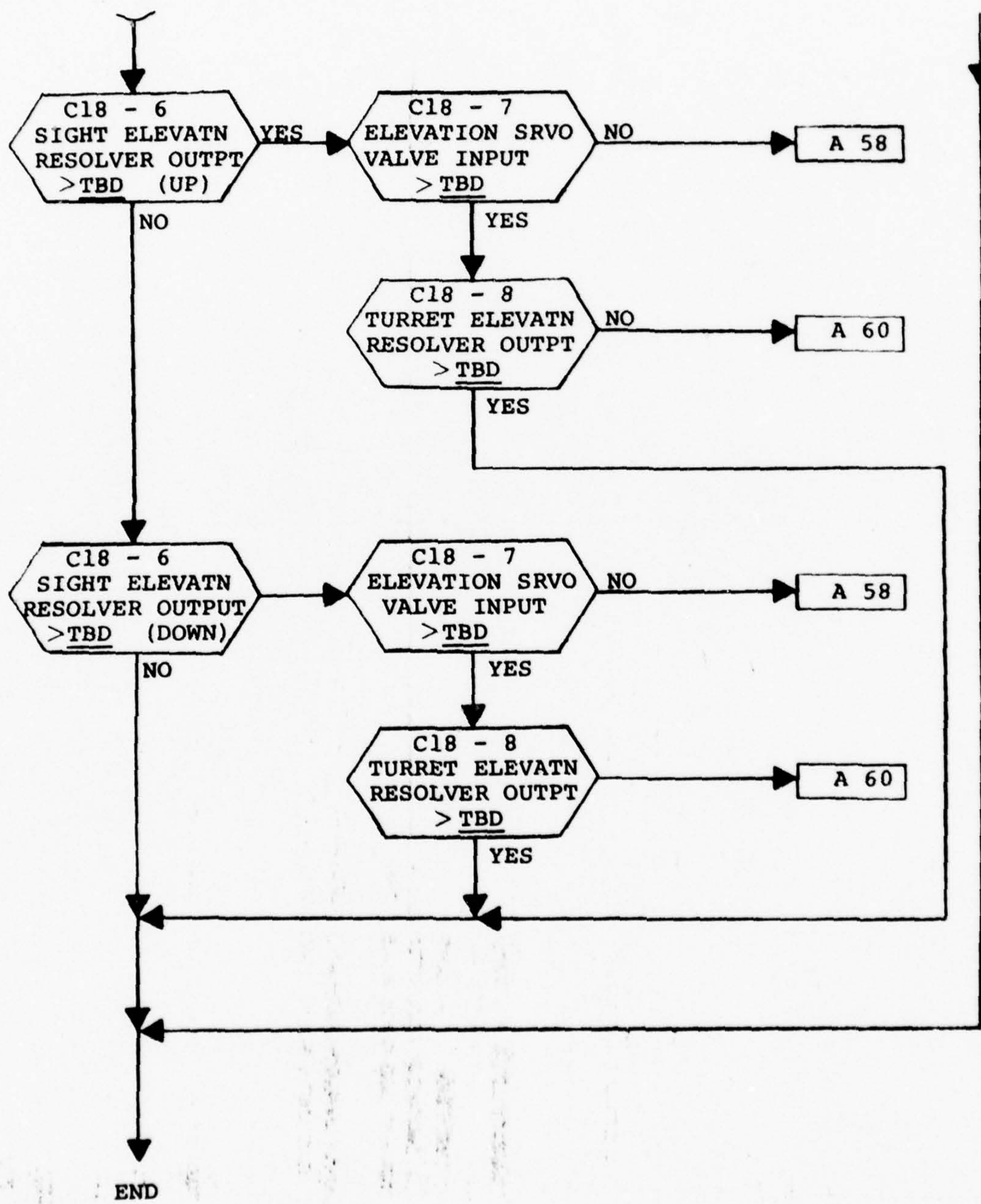

Figure C-18. (Concluded)

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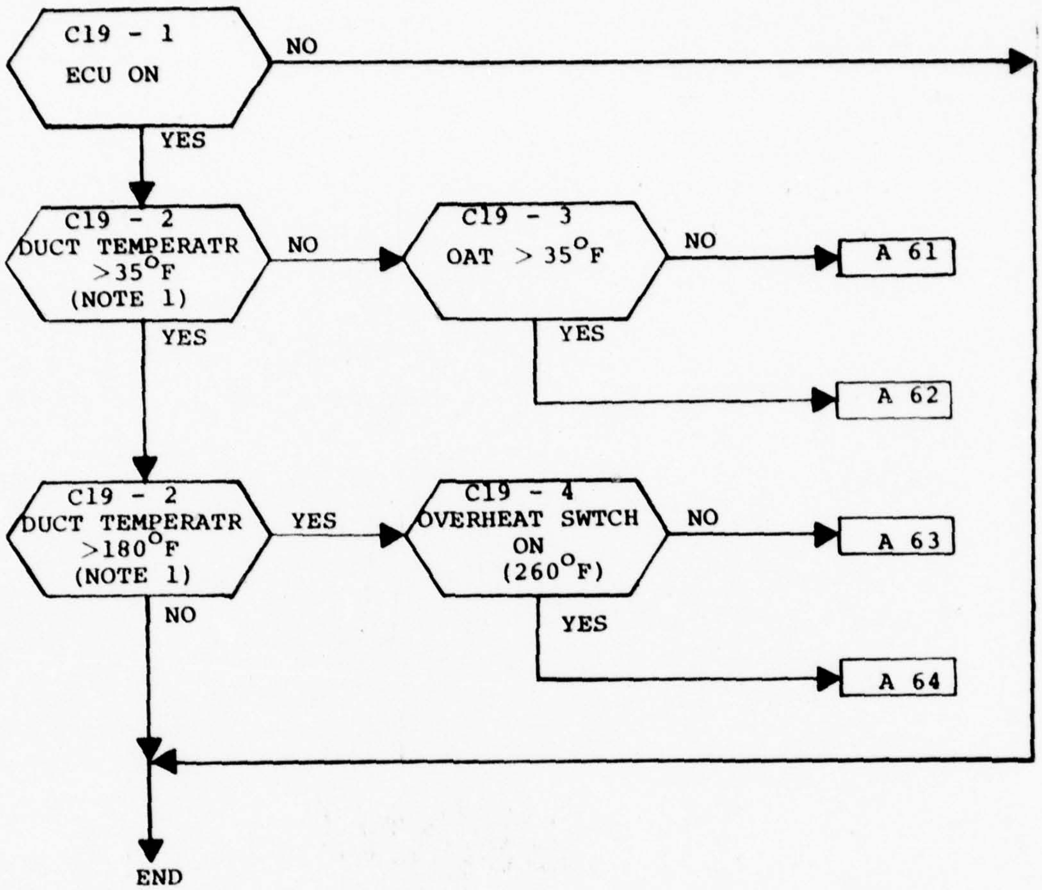

NOTE 1: USE MS TEMPERATURE BULB IN DUCT ADJACENT TO SYSTEM CONTROL SENSOR

Figure C-19. AH-1G environmental control unit (ECU) logic.

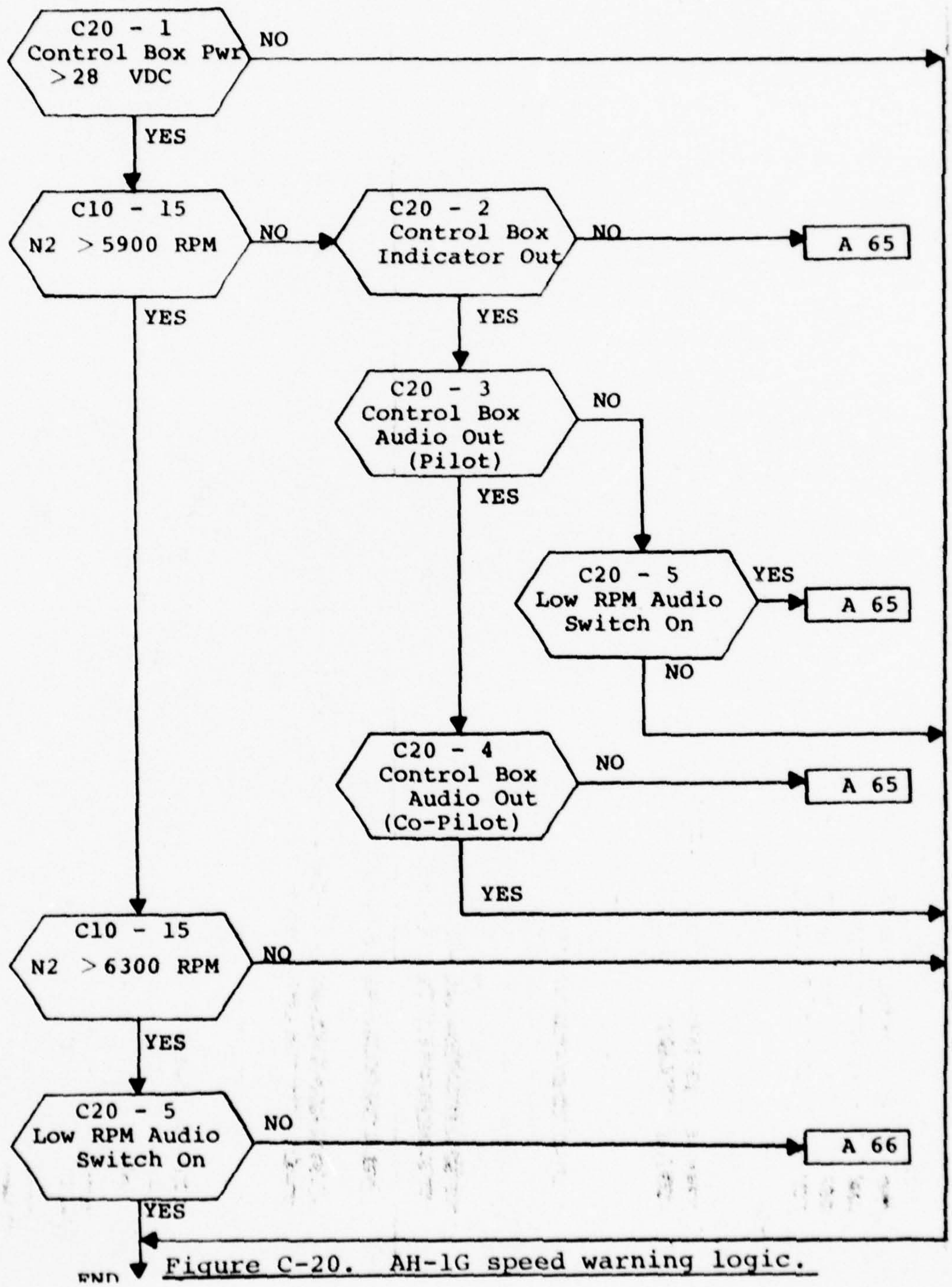

Figure C-20. AH-1G speed warning logic.

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TABLE C-I

UH-1H PARAMETER SYMBOLS AND TEST POINTS

Test Point	*Sensor Availability	Parameter Measured	Symbol
C1-1	1	Engine accessory gearbox chip detector	AGB
C1-2	3	Engine No. 2 bearing chip detector	B2
C1-3	3	Engine No. 3 and 4 bearing chip detector	B3
C1-4	1	Engine gas producer speed	N1
C1-5	3	Engine inlet guide vanes position	IGV
C1-6	3	Engine bleed band position	
C1-7	3	Engine No. 2 bearing scavenge pressure	B2P
C1-8	3	Engine No. 2 bearing ΔT (scavenge - supply)	B2 ΔT
C1-9	1	Engine oil pressure	EOP
C1-10	3	Engine No. 3 and 4 bearing ΔT (scavenge - supply)	B3 ΔT
C1-11	1	Engine oil temperature (supply pump outlet)	EOT
C1-12	1	Engine exhaust gas temperature (average and low)	T_{T_9} & $T_{9_{LO}}$
C1-13	3	Engine oil filter differential pressure	EOF ΔP
C1-14	1	Engine torque	
C1-15	1	Engine output shaft speed	N2
C2-1	1	Xmsn oil supply temperature	XOT
C2-2	1	Xmsn oil supply temperature switch	
C2-3	3	Xmsn oil cooler flow	
C2-4	1	Xmsn oil supply pressure	XOP
C2-5	1	Xmsn oil pressure switch	
C2-6	3	Xmsn internal oil filter	
C2-7	3	Xmsn external oil filter	
C3-1	2	Battery on-off switch position	
C3-2	2	Starter relay	
C3-3	2	Battery voltage	
C3-4	1	Engine average EGT	
C4-1	2	Main generator on-off switch	
C4-2	2	Bus control relay ("C" contacts)	
C4-3	2	Main generator output voltage	
C4-4	2	Main generator load meter	
C5-5	1	Non-essential bus voltage	

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TABLE C-1 (Concluded)

Test Point	*Sensor Availability	Parameter Measured	Symbol
C5-1	1	Stand-by generator switch position	
C5-2	2	Stand-by generator output voltage	
C5-3	1	Stand-by generator load	
C5-4	1	Non-essential bus switch position	
C6-1	2	Inverter switch position	
C6-2	2	Inverter (AC) fail relay position	
C6-3	1	26 VAC instrument transformer	
C7-1	2	Main fuel switch position	
C7-2	1	L/H main fuel tank flow switch	
C7-3	1	R/H main fuel tank flow switch	
C7-4	2	L/H fuel boost pump pressure	
C7-5	2	R/H fuel boost pump pressure	
C7-6	1	Common manifold fuel pressure	
C7-7	1	Fuel filter differential pressure switch	
C7-8	1	Fuel pump element differential pressure switch	
C7-9	3	Fuel flow meter	
C8-1	2	Hydraulic control switch position	
C8-2	3	Hydraulic pump case drain flow	
C8-3	3	Hydraulic system pressure	
C8-4	1	Hydraulic low pressure warning switch	
C8-5	3	Hydraulic system filter differential pressure switch	
C9-1	2	Speed warning control box input power	
C9-2	2	Speed warning control box indicator output	
C9-3	2	Speed warning control box audio output (pilot)	
C9-4	2	Speed warning control box audio output (copilot)	
C9-5	2	Low RPM audio switch position	

*Availability Notes:

1. Sensor available on aircraft
2. New sensor required
3. Sensor presently provided by AIDAPS hardware contractor

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TABLE C-II. AH-1G PARAMETER SYMBOLS AND TEST POINTS

Test Point	*Sensor Availability	Parameter Monitored	Symbol
C10-1	1	Engine accessory gearbox chip detector	AGB
C10-2	2	Engine No. 2 bearing chip detector	B2
C10-3	2	Engine No. 3 and 4 bearing chip detector	B3
C10-4	1	Engine gas producer speed	N1
C10-5	2	Engine inlet guide vane position	IGV
C10-6	2	Engine bleed band position	
C10-7	2	Engine No. 2 bearing scavenge pressure	B2P
C10-8	2	Engine No. 2 bearing ΔT (scavenge - supply)	B2 ΔT
C10-9	1	Engine oil pressure	EOP
C10-10	2	Engine No. 3 and 4 bearing ΔT (scavenge - supply)	B3 ΔT
C10-11	1	Engine oil temperature	EOT
C10-12	1	Engine exhaust gas temperature (average and low)	EGT
C10-13	2	Engine oil filter differential pressure	EOF ΔP
C10-14	1	Engine torque	
C10-15	1	Engine output shaft speed	N2
C11-1	1	XMSN oil supply temperature	XOT
C11-2	1	XMSN oil cooler by-pass indicator	
C11-3	2	XMSN oil cooler flow	
C11-4	1	XMSN sump chip detector	
C11-5	1	XMSN oil pressure	XOP
C11-6	2	XMSN internal oil filter differential pressure	
C11-7	2	XMSN external oil filter differential pressure	
C11-8	1	XMSN oil temperature switch	XOT SW.
C11-9	1	XMSN oil pressure switch	XOP SW.
C12-1	1	Main fuel switch status	
C12-2	1	R/H fuel boost pump pressure switch status	
C12-3	1	L/H fuel boost pump pressure switch status	
C12-4	1	Fuel filter differential pressure switch status	
C12-5	1	Fuel control pump elements differential pressure switch status	
C12-6	2	Fuel flow	
C13-1	1	Battery switch status	
C13-2	1	Gunners power switch status	

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TABLE C-II. (Continued)

Test Point	*Sensor Availability	Parameter Monitored	Symbol
C13-3	1	Start relay status	
C13-4	1	Battery voltage	
C13-5	1	Engine average EGT	
C14-1	1	Pilots starter/generator switch status	
C14-2	1	DC generator voltage output	
C14-3	1	DC generator amperage output	
C14-4	1	DC generator "Out Lite" status	
C15-1	1	AC inverter switch status	
C15-2	1	AC fail relay status	
C15-3	1	Main AC inverter output voltage	
C15-4	1	AC instrument bus voltage	
C16-1	2	No. 2 hydraulic pump outlet pressure	
C16-2	2	No. 2 hydraulic pump case drain flow	
C16-3	2	No. 2 hydraulic system inlet filter differential pressure	
C16-4	2	No. 2 hydraulic system outlet filter differential pressure	
C17-1	1	SCAS pitch channel "No-Go" lite status	
C17-2	1	SCAS pitch channel hydraulic shut-off valve solenoid status	SOV
C17-3	2	SCAS pitch actuator hydraulic inlet pressure	
C17-4	1	SCAS pitch motion input transducer validity	
C17-5	2	SCAS sensor amplifier unit output current and polarity	SAU
C17-6	2	SCAS pitch actuator feedback voltage and phase	
C18-1	1	Armament system hydraulic shut-off-valve solenoid status	SOV
C18-2	2	Armament system pressure downstream of shut-off valve	SOV
C18-3	1	Sight azimuth position resolver output	
C18-4	1	Turret azimuth control servo input voltage	
C18-5	1	Turret azimuth position resolver output	
C18-6	1	Sight elevation position resolver output	

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TABLE C-II. (Concluded)

Test Point	*Sensor Availability	Parameter Monitored	Symbol
C18-7	1	Turret elevation control servo input voltage	
C18-8	1	Turret elevation position resolver output	
C19-1	1	Environmental control unit switch status	ECU
C19-2	2	Environmental control unit duct temperature	
C19-3	1	Outside air temperature	OAT
C19-4	1	Environmental control unit overheat switch	O/H

*Availability Notes:

1. Sensor available on aircraft
2. New sensor required

TABLE C-III. UH-1H AIDAPS MAINTENANCE MESSAGES

Message No.	Failures and/or Instructions
U 1	Inspect and classify chips in the accessory gearbox and No. 2 Bearing Chip Detectors. Check and clean engine oil filter.
U 2	Inspect and classify chips in the accessory gearbox and Nos. 3 and 4 Bearing Chip Detectors. Check and clean engine oil filter.
U 3	Inspect and classify chips in accessory gearbox chip detector. Clean and check engine oil filter.
U 4	Inspect and classify chips on No. 2 Bearing Chip Detector. Clean and check engine oil filter.
U 5	Inspect and classify chips on Nos. 3 and 4 Bearing Chip Detector. Check and clean engine oil filter.
U 6	Replace engine.
U 7	Perform special overspeed inspection per TM55-1520-210-20 and perform any indicated gas path maintenance. If no gas path maintenance is indicated perform torque topping adjustments per TM55-1520-210-20. If proper topping adjustments cannot be produced, replace fuel control.
U 8	1. Inspect IGV rigging or 2. Replace fuel control
U 9	1. Inspect bleed band rigging or 2. Replace fuel control
U 10	Replace No. 2 bearing seals
U 11	1. Oil level low or 2. Oil lines clogged or 3. Adjust or replace relief valve or 4. Replace oil pump
U 12	1. Clean oil strainer on No. 2 bearing or 2. Replace No. 2 bearing seals or 3. Replace No. 2 bearing
U 13	1. Clean oil strainer - Nos. 3 and 4 bearing or 2. Replace seals or 3. Replace No. 3 or No. 4 bearing

TABLE C-III. (Continued)

Message No.	Failures and/or Instructions
U 14	1. Check for FOD blocking fan or 2. Replace oil cooler blower
U 15	1. Inspect reduction gearbox or 2. Replace thermo by-pass valve
U 16	Replace EGT thermocouple
U 17	Clean engine oil filter
U 18	Perform "excessive engine torque" special inspection per TM55-1520-210-20 for torque > 73 PSI
U 19	Same as U 18 for torque > 61 PSI
U 20	Same as U 18 for torque > 54 PSI
U 21	Same as U 18 for torque > 50 PSI
U 22	Perform "N2 overspeed special inspection" per TM55-1520-210-20
U 23	1. Check oil cooler and lines for internal blockage or 2. Replace xmsn oil cooler thermal bypass valve or 3. Replace xmsn oil pump
U 24	Secondary effect causing xmsn oil temp to increase-check vibration printouts and chip detector for evidence of xmsn internal failure
U 25	1. Replace or adjust relief valve or 2. Replace oil pump
U 26	Replace or adjust relief valve
U 27	Clean xmsn internal filter
U 28	Clean xmsn external filter
U 29	1. Replace battery or 2. Replace battery charger
U 30	Replace battery
U 31	Hot start inspection
U 32	Replace Bus control relay

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TABLE C-III. (Continued)

Message No.	Failures and/or Instructions
U 33	Replace main gen. reverse current relay
U 34	1. Replace generator or 2. Replace field relay or 3. Replace overvoltage relay or 4. Adjust or replace voltage regulator
U 35	1. Replace field relay or 2. Replace voltage regulator or 3. Replace generator
U 36	1. Adjust voltage regulator or 2. Replace generator
U 37	Replace reverse current relay
U 38	Replace non-essential bus control relay
U 39	Replace main inverter
U 40	Replace spare inverter
U 41	Replace instrument transformer
U 42	Replace L/H fuel boost pump
U 43	Replace L/H flow switch
U 44	Replace R/H fuel boost pump
U 45	Replace R/H flow switch
U 46	Replace manifold pressure transmitter
U 47	Clean fuel filter
U 48	Replace fuel control (pump element)
U 49	Replace fuel shut-off valve
U 50	Replace hydraulic pump
U 51	1. Replace hydraulic shut-off valve or 2. Adjust or replace relief valve or 3. Replace hydraulic pump
U 52	1. Replace hydraulic pressure transmitter or 2. Replace pressure switch

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TABLE C-III. (Concluded)

Message No.	Failures and/or Instructions
U 53	1. Adjust or replace hydraulic relief valve or 2. Replace hydraulic pump
U 54	Replace hydraulic press switch
U 55	Adjust or replace relief valve
U 56	Clean hydraulic filter
U 57	Replace speed warning system control box
U 58	Replace low RPM audio switch

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TABLE C-IV. AH-1G AIDAPS MAINTENANCE MESSAGES

Message No.	Failures and/or Instructions
A 1	Inspect and classify chips in the accessory gearbox and No. 2 Bearing Chip Detectors. Check and clean engine oil filter.
A 2	Inspect and classify chips in the accessory gearbox and Nos. 3 and 4 Bearing Chip Detectors. Check and clean engine oil filter.
A 3	Inspect and classify chips in accessory gearbox chip detector. Clean and check engine oil filter.
A 4	Inspect and classify chips on No. 2 Bearing Chip Detector. Clean and check engine oil filter.
A 5	Inspect and classify chips on Nos. 3 and 4 Bearing Chip Detector. Check and clean engine oil filter.
A 6	Replace engine.
A 7	Perform special overspeed inspection per TM55-1520-221-20 and perform any indicated gas path maintenance. If no gas path maintenance is indicated perform torque topping adjustments per TM55-1520-221-20. If proper topping adjustments cannot be produced, replace fuel control.
A 8	1. Inspect IGV rigging or 2. Replace fuel control
A 9	1. Inspect bleed band rigging or 2. Replace fuel control
A 10	Replace No. 2 bearing seals
A 11	1. Oil level low or 2. Oil lines clogged or 3. Adjust or replace relief valve or 4. Replace oil pump
A 12	1. Clean oil strainer on No. 2 bearing or 2. Replace No. 2 bearing seals or 3. Replace No. 2 bearing
A 13	1. Clean oil strainer - Nos. 3 and 4 bearing or 2. Replace seals or 3. Replace No. 3 or No. 4 bearing

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TABLE C-IV. (Continued)

Message No.	Failures and/or Instructions
A 14	1. Check for FOD blocking fan or 2. Replace oil cooler blower
A 15	1. Inspect reduction gearbox or 2. Replace thermo by-pass valve
A 16	Replace EGT thermocouple
A 17	Clean engine oil filter
A 18	Perform "excessive engine torque" special inspection per TM55-1520-221-20 for torque >73 PSI
A 19	Same as A 18 for torque > 63 PSI
A 20	Same as A 18 for torque > 54 PSI
A 21	Same as A 18 for torque > 50 PSI
A 22	Perform "N2 overspeed special inspection" per TM55-1520-221-20
A 23	XMSN oil cooler leak
A 24	Oil cooler blower
A 25	XMSN oil cooler thermo-valve
A 26	Internal XMSN damage - magnetic mat'l - classify debris on chip detector per TM55-1520-221-20
A 27	Internal XMSN damage - non magnetic mat'l - check pump screen and filters
A 28	XMSN oil pressure relief valve
A 29	1. XMSN oil pump or 2. XMSN oil cooler by-pass valve or 3. XMSN oil pressure relief valve
A 30	Internal XMSN filter by-pass - clean filter and flush system
A 31	External XMSN filter by-pass - replace filter element and flush system
A 32	R/H fuel boost pump
A 33	L/H fuel boost pump

TABLE C-IV. (Continued)

Message No.	Failures and/or Instructions
A 34	Fuel filter ΔP switch on - clean filter
A 35	Fuel control (pump element)
A 36	Fuel shut-off valve closed
A 37	Battery
A 38	Hot start - perform special inspection per TM55-1520-221-20
A 39	1. Generator or 2. Field relay or 3. Voltage regulator
A 40	Reverse current relay
A 41	1. Bus control relay or 2. Reverse current relay
A 42	1. Inverter control relay or 2. Inverter relay or 3. Thermo switch or 4. Main inverter
A 43	Main inverter
A 44	Spare inverter
A 45	Instrument transformer
A 46	Hydraulic pump No. 2 (compensator)
A 47	Hydraulic pump No. 2 (high case drain)
A 48	Hydraulic system No. 2 inlet filter impending by-pass
A 49	Hydraulic system No. 2 return filter impending by-pass
A 50	1. Hydraulic pump No. 2 or 2. Relief valve
A 51	1. SCAS pitch channel hydraulic shut-off-valve (solenoid) or 2. SCAS control panel

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TABLE C-IV. (Concluded)

Message No.	Failures and/or Instructions
A 52	SCAS pitch channel hydraulic shut-off valve
A 53	1. SCAS pitch motion transducer (shorted) or 2. Sensor amplifier unit
A 54	SCAS pitch motion transducer (open)
A 55	SCAS pitch actuator
A 56	SCAS sensor amplifier unit
A 57	Armament system hydraulic shut-off-valve
A 58	Gun turret electronic control box
A 59	1. Turret azimuth servo valve or 2. Turret azimuth hydraulic motor or 3. Turret azimuth position resolver
A 60	1. Turret elevation servo valve or 2. Turret elevation hydraulic actuator or 3. Turret elevation position resolver
A 61	1. ECU pressure regulator and shut-off valve or 2. ECU air distribution valve or 3. ECU overheat switch
A 62	1. ECU control sensor (open) or 2. ECU control box (low limit)
A 63	1. ECU control sensor (short) or 2. ECU control box (high limit) or 3. ECU add heat valve
A 64	Major ECU failure - check: A. Ram air circuit B. Temperature control circuit C. ECU turbine D. Reheater circuit
A 65	Replace speed warning system control box
A 66	Replace low RPM audio switch

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APPENDIX D
UH-1H/AH-1G AIDAPS PROTOTYPE INSTALLATION VIBRATION AND TEMPERATURE ENVIRONMENT

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D-1.0 INTRODUCTION

UH-1H and AH-1G helicopter environmental data in the installation areas of the prototype AIDAPS Data Acquisition Unit and Computer/Tape Recorder was provided per Airesearch request. Airesearch personnel indicated that in the UH-1H, both units would be located in the forward upper area of the heater compartment and in the AH-1G, one or both units would be installed behind the pilot, or in the tailboom just forward of the horizontal stabilizer. The equipment is designed to meet the MIL-E-5400, Class 2 environment for operation in both aircraft and helicopters. Airesearch personnel also indicated that the equipment will be tested using the guidelines of MIL-STD-810.

D-2.0 TEMPERATURE ENVIRONMENT

D-2.1 Measured Temperatures in the AH-1G Helicopter Tailboom

A tailboom temperature survey was conducted on an AH-1G flight test aircraft at the BHT flight test facility. Internal tailboom temperatures were recorded at the following positions shown in Figure D-1.

TC#	Fuselage Location
1	Station 275 @ tail break
2	Station 318 @ second tailboom bulkhead
3	Station 340 @ third tailboom bulkhead
4	Station 360 @ fourth tailboom bulkhead
5	Station 381 @ fifth tailboom bulkhead

The helicopter was parked in the sun for two hours before flight. A test flight was conducted in bright sunlight and low altitude. The flight profile and temperatures measured are as follows:

Profile	Temperature in ^{o}F					
	OAT	#1	#2	#3	#4	#5
On ground engine off	88	94	100	101	101	101
2 minutes @ flight idle	88	98	101	102	103	109
1 minute ground run @ 324 rpm	88	91	106	112	118	119
5 minutes ground run @ 324 rpm	89	109	118	181	136	144
1 minute hover	89	104	122	138	138	156
5 minute hover	89	109	114	134	143	161
2 minutes level flight @ 120 knots	89	109	129	137	142	149
5 minutes level flight @ 120 knots	89	102	119	122	135	124
10 minutes level flight @ 120 knots	89	111	120	123	134	120

The cockpit of the AH-1G helicopter is air conditioned and no cooling problem is anticipated at this location. No temperature data is available for the upper heater compartment in the UH-1H

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helicopter; however, there are various avionic installations in this area in BHT commercial model configurations with no apparent cooling problems.

D-3.0 VIBRATION ENVIRONMENT

The principal sources of sinusoidal excitation below 500 Hz for the UH-1H and AH-1G are identical and listed in Table D-I. The equipment design should avoid resonance within $\pm$ 10% of these frequencies. Two or more sources may produce nearly the same frequency, such as the main rotor 10/rev and tail rotor 2/rev. These closely spaced frequencies are not distinguished in the enclosed data. Gunfiring frequencies are not listed in Table D-I, because the filters used in the available data smeared the predominant peaks into a broad band spectrum.

Figures D-2 and D-3 show the acceleration vs. frequency data for the AH-1G behind the pilot and in the tailboom forward of the elevator. Figure D-4 shows the data for the UH-1H heater compartment. The diamonds designate values below which 99% of the harmonic data fall. Firing data from two sources is presented in Figures D-2, D-3, and D-4. Figure D-4 presents a discontinuous firing envelope which indicates that the firing did not change the low frequency steady-state spectrum. Figure D-5 presents a composite of the combined environments of Figures D-2, D-3, and D-4, The curves do not distinguish direction; fore and aft, lateral and vertical are combined.

Test procedures following the guidelines of MIL-STD-810 are recommended substituting the "BHT recommended" curve of Figure D-5 for Figure 514.1-3 of MIL-STD-810B, Notice 4. The test curve of Figure D-5 assumes that tests at a given harmonic must be at a higher level than the filtered data since other harmonics are present. The "BHT recommended" line was developed as the 99% value for the harmonic plus half the sum of the other harmonics. For gunfiring, 10 harmonics of $\pm$ 0.5g are considered simultaneously present. The sweep tests of MIL-STD-810 are considered adequate to cover the gunfire vibration environment.

Recommended modifications to MIL-STD-810; Method 514.1, Vibration; Paragraph 4, Test Procedures; are as follows:

4.1 Test item operation - In the event of component failure during testing, considerations for repeating the entire test sequence, or portions of the test sequence, shall be made by the contracting agency prior to replacement or repair of the component and resumption of testing.

4.5.1 Sinusoidal vibration tests - Perform the same test in the three principal directions.

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4.5.1.1 Resonance search - May be omitted unless required for design information purposes.

4.5.1.2 Resonance dwell - Substitute harmonic dwell at the marked (diamond) frequencies at the level of the "BHT recommended" curve of Figure D-5 for a duration of 20 minutes along each axis.

4.5.1.3 Cycling - Follow the "BHT recommended" curve of Figure D-5 for a duration of 1.5 hours along each axis.

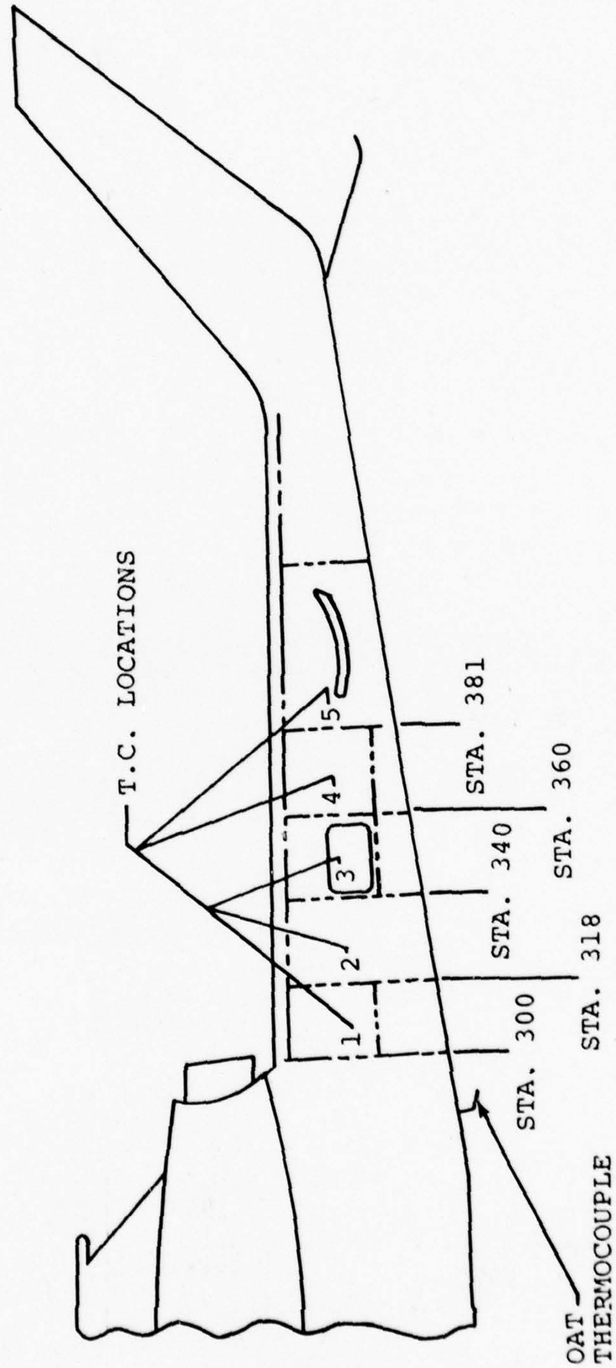

Figure D-1. Thermocouple fuselage locations.

TABLE D-I

UH-1H AND AH-1G VIBRATION SOURCES

Main Rotor Speed: 324 RPM

Source		Frequency (Hz)
Main Rotor	Fundamental	5.4
	2/rev	10.8
	4/rev	21.6
	6/rev	32.4
	8/rev	43.2
	10/rev	54.0
	12/rev	64.8
	14/rev	75.6
Tail Rotor	Fundamental	27.6
	2/rev	55.1
	4/rev	110.2
	6/rev	165.3
	8/rev	220.4
Tail Rotor Drive Shaft		72
Engine Shaft		110
Power Turbine		351
Gas Producer (100%)		419

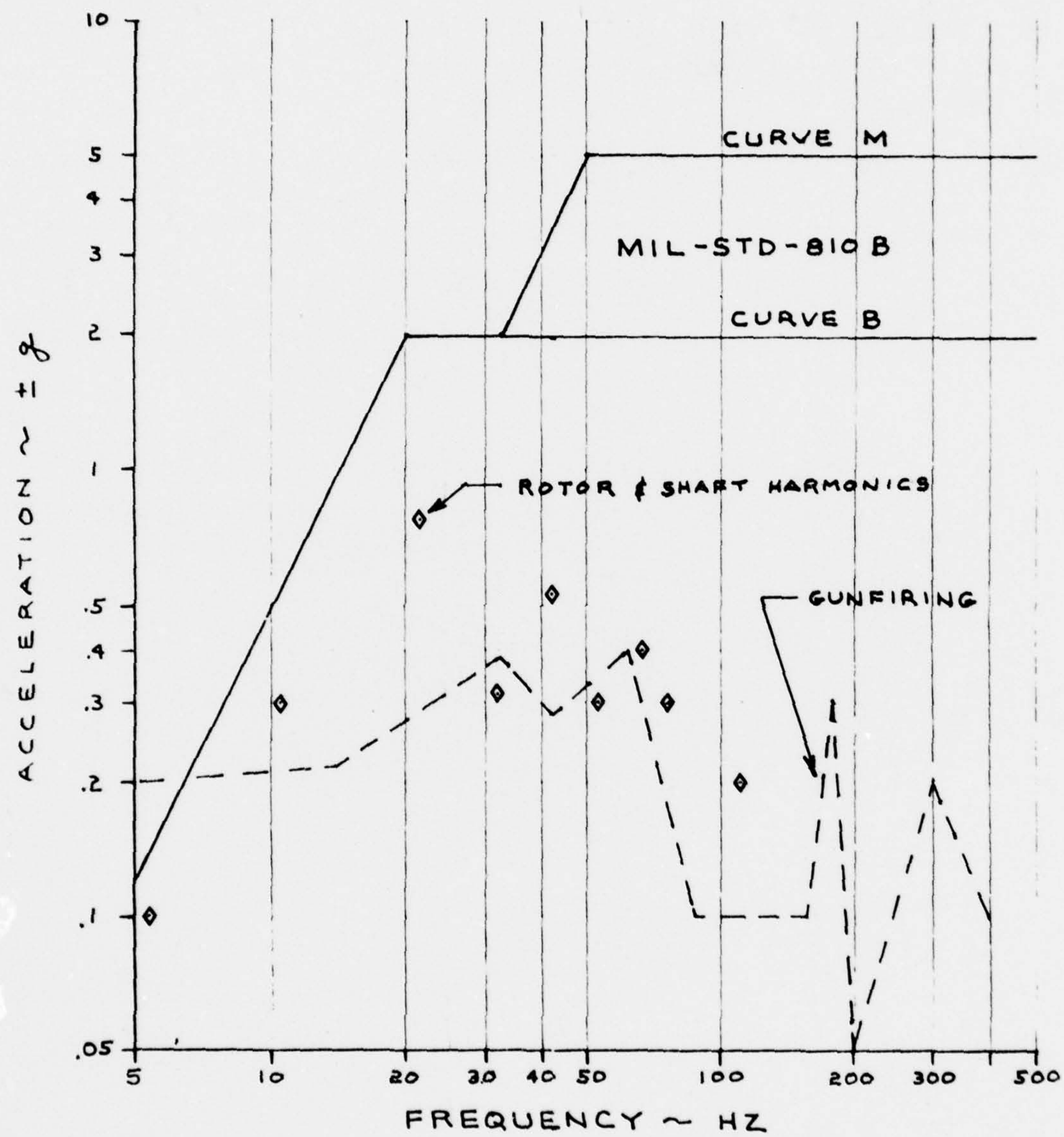

Figure D-2. AH-1G vibration environment behind pilot.

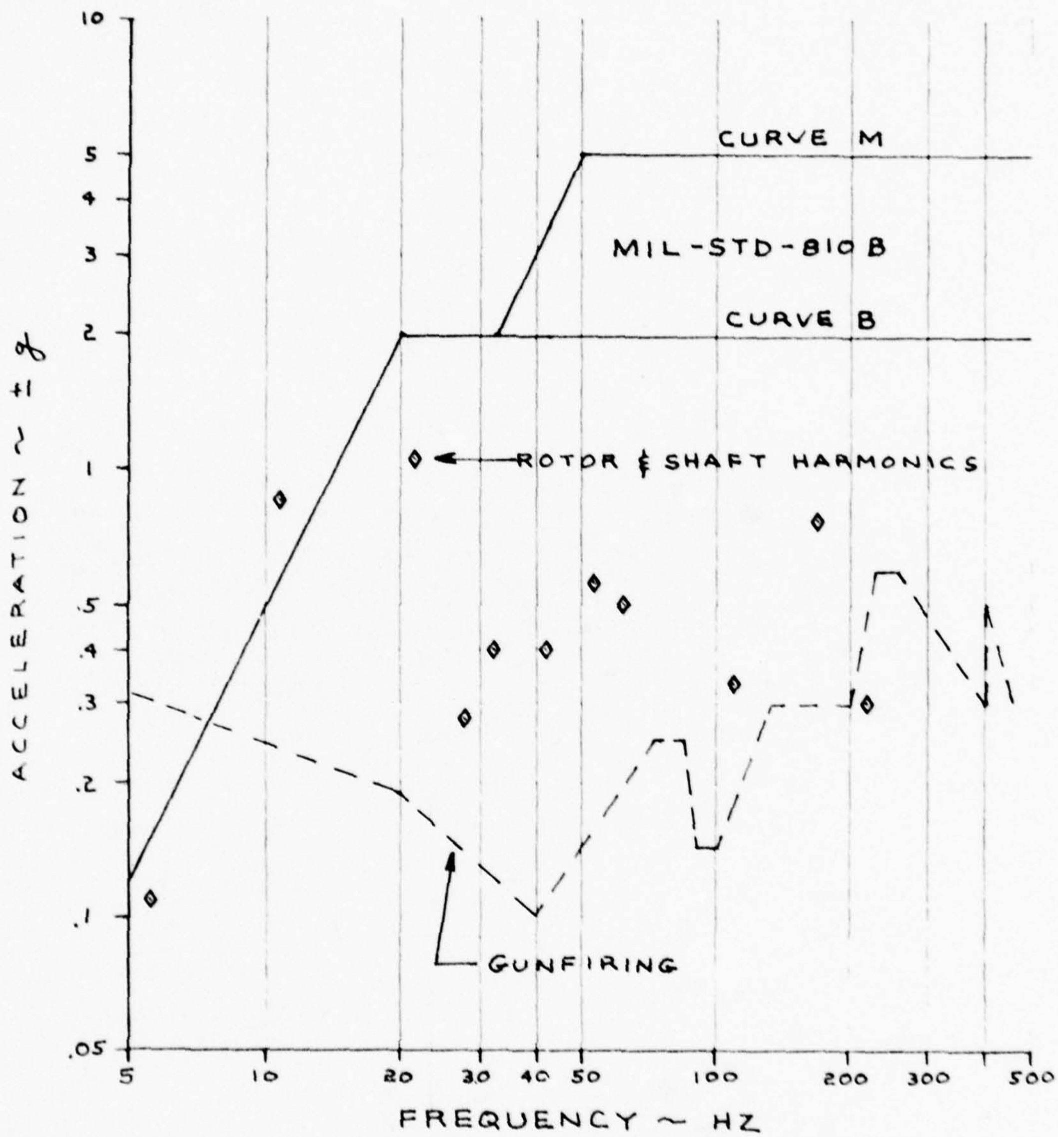

Figure D-3. AH-1G vibration environment - tail boom forward of elevator.

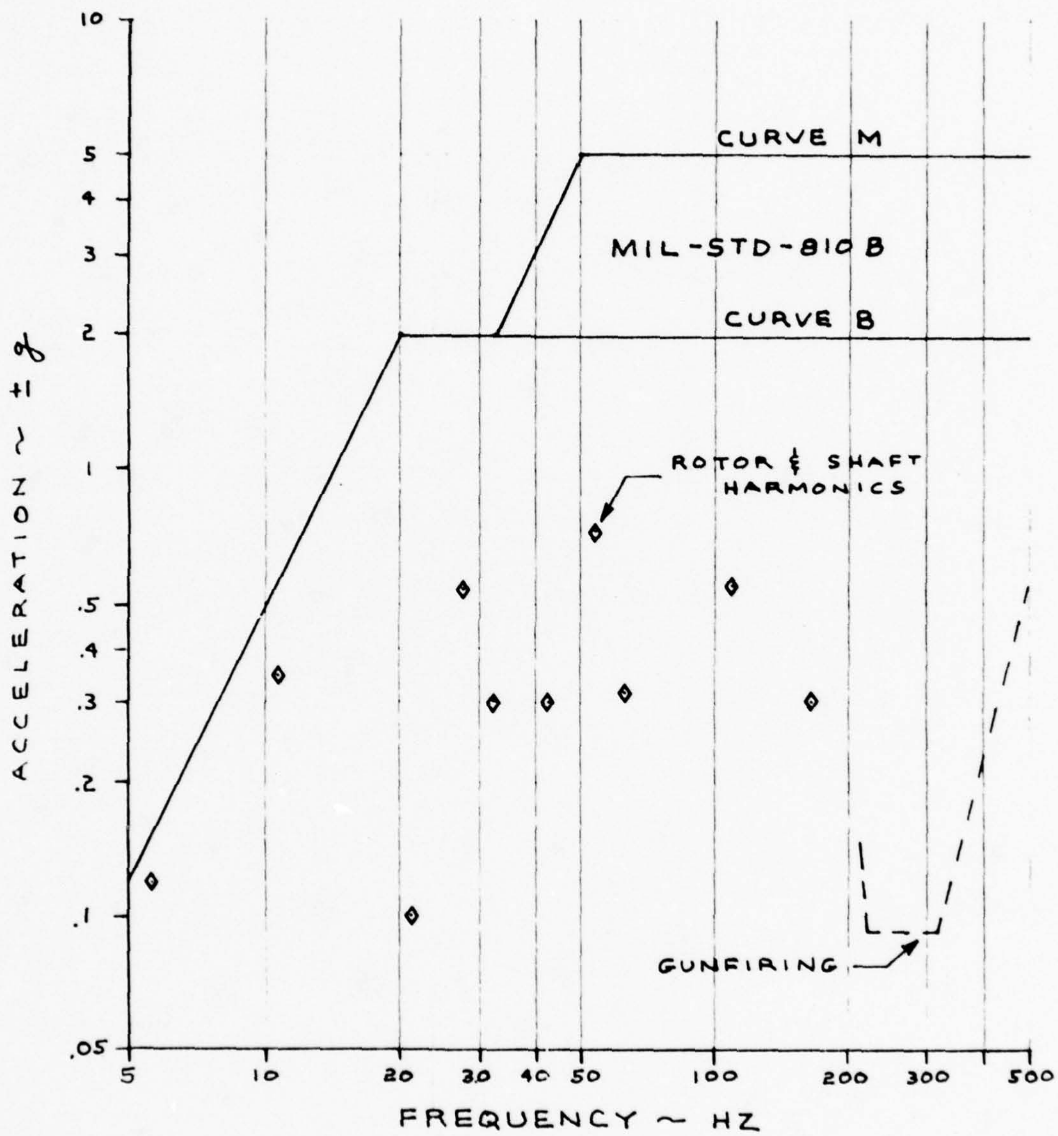

Figure D-4. UH-1H vibration environment - heater compartment.

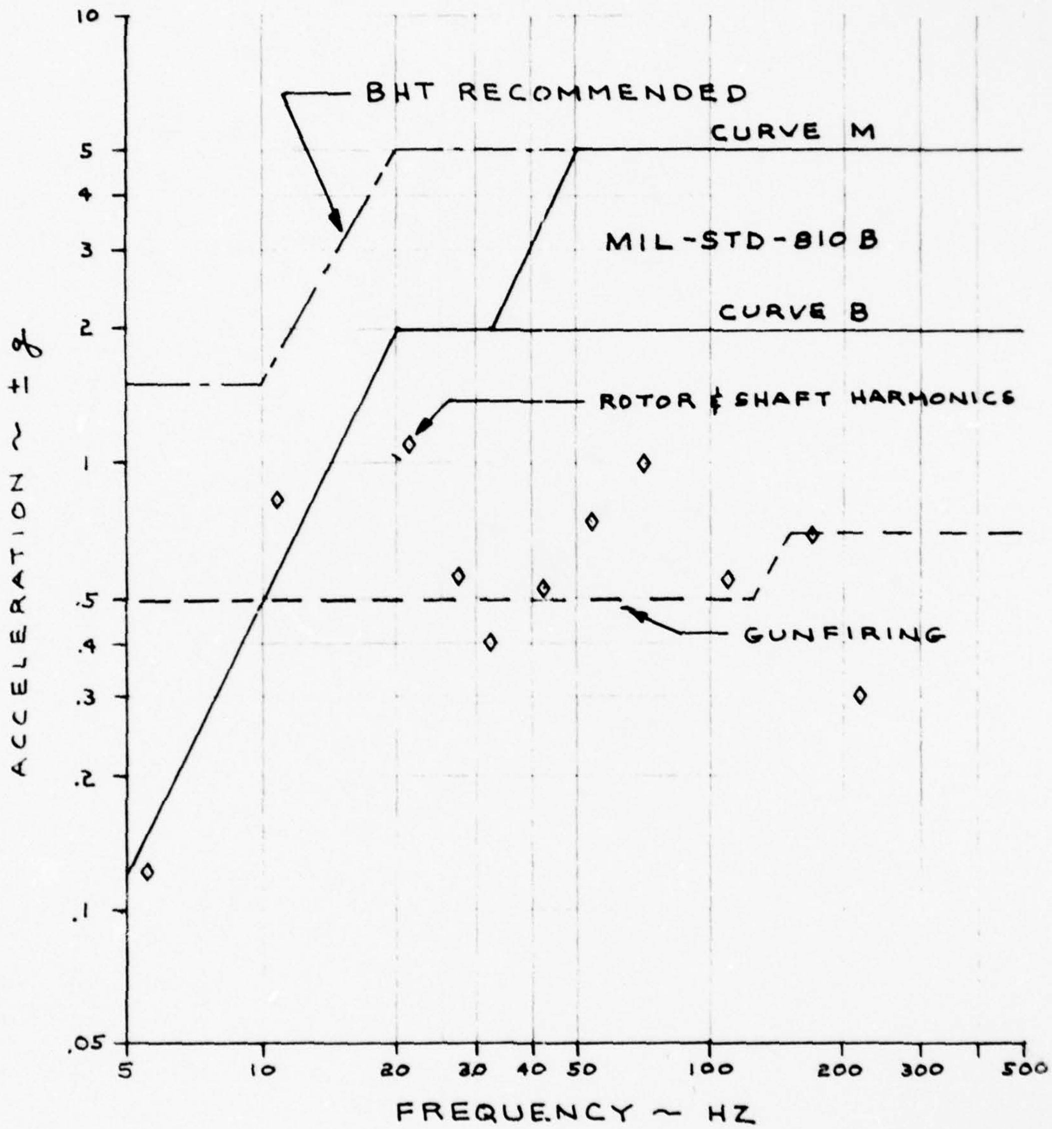

Figure D-5. UH-1/AH-1 composite vibration environment.

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APPENDIX E

IMPLANT PART DATA

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E-1.0 IMPLANT PART HISTORY AND DESCRIPTION

E-1.1 Provision, Inspection and Grading Of Parts

AVSCOM provided bearing and gear implant candidates that were rejects selected from overhaul depots, gathered and stored in the U.S. Army Headquarters and Installation Activity at Granite City, Illinois. The implant candidates were inspected and graded by BHT personnel and installed in transmissions and gearboxes at the BHT transmission test laboratory for diagnostic and prognostic data collection and/or validation as flight test candidates for the AIDAPS flight test data collection effort at Fort Rucker, Alabama. The technical quantitative grading system is presented in the body of this report and was developed from the understanding of the non-technical qualitative grading developed and discussed during the initial AIDAPS co-ordination meetings. The qualitative grading system was used at Fort Rucker, Alabama, as described in the U.S. Army Test Board Project No. 4-ES-645-ADS-002, "Flight Data Collection Phase Final Report," dated November 1975. The grading system defines four categories:

Category	Description
"A"	Parts which meet serviceability requirements
"B"	Parts at or just over the overhaul rejection criteria but considered flightworthy for testing purposes
"C"	Parts beyond the overhaul rejection criteria but considered flightworthy for testing purposes
"D"	Parts well beyond the overall rejection criteria and not considered flightworthy.

E-1.2 Operating Limitations

During the flight test data reduction effort, AVSCOM issued thirty-hour flight releases for implants in categories "A," "B," and "C." Although the flight release was for thirty hours, BHT recommended to the Fort Rucker personnel that the implants be limited to five hours of test operations between inspections. It was also recommended that gear implants be magnafluxed and inspected for cracks in the gear teeth in and adjacent to the scoring damage. The inspection was repeated after every five hours of test operation. Five hours provided sufficient time for a maintenance tiedown run, maintenance check flight and a data reduction flight.

The implants in Category "D" were recommended by BHT for cell test use only. AVSCOM issued a release to Fort Rucker for the "D" category implants to be installed in gearboxes and transmissions for ground run and tiedown operations during the flight test data reduction effort. Some Category "D" implants were selected by

AVSCOM for flight release during the AIDAPS prototype flight test effort, apparently based on the experience gained during the flight test data collection effort and the preliminary results of the Removal Limit Confidence Test presented to AVSCOM in BHT Letter 81:JVH:bw-425, dated 19 April 1976.

Implant part numbers BHC-053, -065, and -122 are hanger bearings. These parts cannot be inspected prior to operation because they are sealed bearings which must be cut apart for inspection. As a result, these bearings were operated for data collection purposes at Fort Rucker, and then cut open, inspected and classified as "A," "B," "C," or "D." Recommended operating restrictions were issued on the implant part description and inspection data sheets for the hanger bearings installed on the UH-1H AIDAPS test helicopters as follows:

- Ground run @100% RPM to light-on-skids condition. Monitor the bearing by sound and feel for excessive vibration.

- Shut down and inspect the bearing visually for slinging grease or heat (smoke or discoloration).

- If any of the above conditions are noted, the helicopter should not be flown, but may be operated on the tiedown pad.

- Release for one-time flight if vibration, grease slinging or heat is not present. Repeat the above inspections before release for next flight.

E-1.3 Implant Installation

Installation notes concerning the bearing outer race defect orientation and the installation of gear sets were noted on the implant part inspection and description data sheets. Most gear sets were installed with a random orientation of gear teeth. Some 90-degree gearbox implants were scored on every third tooth and the mating teeth were marked for installation orientation. BHC implant part numbers 016 & 017, 028 & 029, 033 & 034, 036 & 037, 040 & 041, 044 & 046, 049 & 051, 069 & 075, 070 & 071, 072 & 073, 101 & 102, 109 & 106, 111 & 112, 113 & 114, 115 & 116, 127 & 128, 130 & 131, 134 & 135, 136 & 137, 138 & 139 were operated as sets.

E-1.4 Implant Requirements and Degradation Provisions

The AIDAPS hardware developer required implants in the upper limit "C" to "D" category degradation. The parts collected from the overhaul facilities were mostly in the "B" category degradation; however, a sufficient number of gear candidates in the "D" category were available. A great amount of time was dedicated during the subject program to artificially degrading bearing implants and validating them in the BHT test cell in order to

adequately support the flight test data collection effort conducted by the AIDAPS hardware developer at Fort Rucker. It was found through experimentation that artificial spalls could be simulated in the bearing elements by a vibro etching tool. The data from comparable artificially and naturally degraded bearings verified that the signatures were similar. The MAIC program described in Appendix F was conducted to supply fatigue-induced defective bearings for use in the prognostic testing conducted at BHT.

Implant part numbers BHC-117 through BHC-120 were reserved for implants provided to Fort Rucker by AVSCOM through Parks College, Cahokia, Illinois. The implants provided were two 204-040-330 sun gears and one 204-040-700/701 input pinion and gear set. All were artificially degraded by grinding grooves near the pitch line in the gear tooth face. BHT personnel inspected these gears at Fort Rucker and reported to AVSCOM in Monthly Progress Report No. 26, (July 1975) that "--this method of artificially degrading gears is not indicative of a natural fault, and should not be used for evaluating diagnostic signature data." Because the artificial degradation does not simulate a natural fault, these implants are not documented in this appendix.

E-1.5 Documentation and Operating History

Implant part inspection and data sheets documented the implants during the AIDAPS testing as outlined in the body of the report. The picture descriptions and operating histories of the bearing and gear implants provided by BHT are presented in Figures E-1 through E-158. Except for hanger bearings, the photographs show the initial condition of the implant. However, in most cases, there was negligible change in the condition of the implant during its installation history. Hanger bearings must be cut apart in order to be inspected, and therefore are shown at the end of their installation history. Some of the hanger bearings were not inspected, in which case no photograph is available.

In reviewing Figures E-1 through E-158, it may be noted that some numbers are missing from the implant numbering sequence. Numbers BHC-117, -118, -119, and -120 are not included, as noted in Paragraph E-1.4 above. Similarly, numbers BHC-107 and -108 were provided to the Test Board for assignment to hanger bearing implants at Ft. Rucker, and are therefore not included herein. Finally, certain numbers were never used for a variety of reasons. The unused BHC series numbers are -045, -066, -100, -121, and -125. Other AIDAPS implants which are not described in this report are the "AID" (Lycoming) series and the "ATB" (Test Board) series.

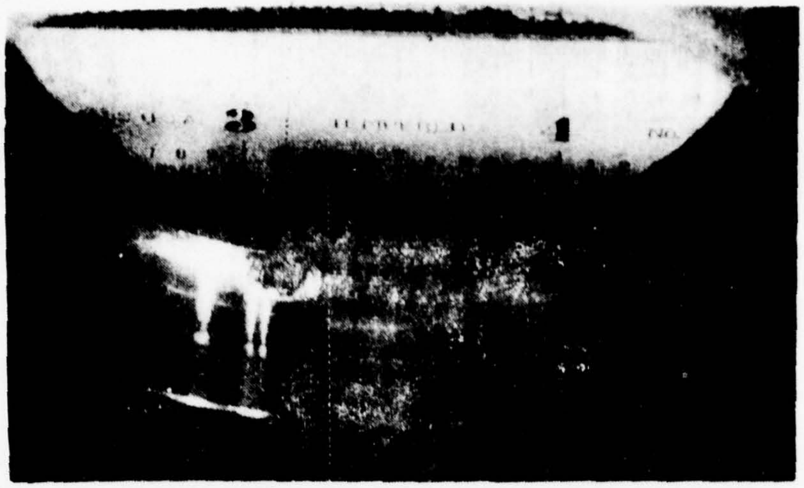

Figure E-1
Implant BHC-001
Ball Bearing P/N 204-040-143, S/N 28346
Natural Category "D" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		12/73	1.7	Part Validation
	X		X		6/74	3.7	Data Collection
	X		X		7/74	2.0	Data Collection
	X			X	10/74	6.4	Data Collection
	X	X			11/74	4.2	Data Collection
	X		X		12/74	2.8	Data Collection
X			X		3/75	5.4	Degradation Rate Tests
X			X		3/75	40.5	Degradation Rate Tests
X			X		4/75	80.0	Degradation Rate Tests
	X			X	7/75	3.0	Data Collection
X			X		1/76	91.8	Removal Limit Confidence Test
	X		X		4/76	7.0	Prototype Testing
	X	X			9/76	4.4	
	X			X	10/76	5.7	
						258.6	Total Time

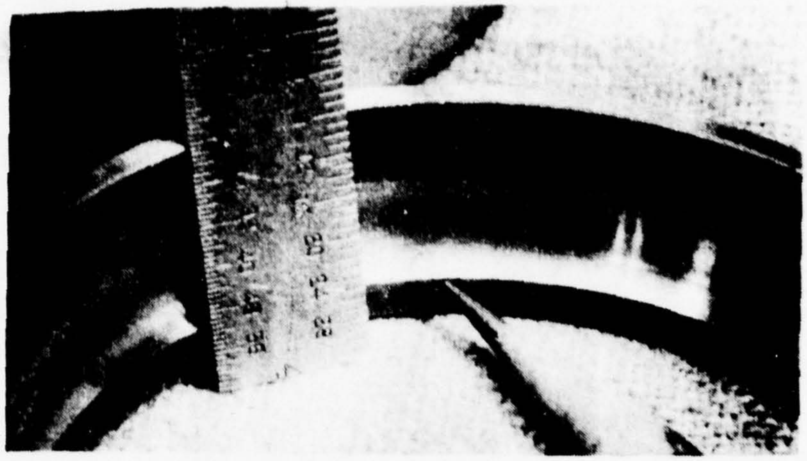

Figure E-2
Implant BHC-002
Ball Bearing P/N 204-040-143, S/N 34636
Natural Category "B" Outer Race Pit

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
X			X		3/74	1.8	Part Validation
	X		X		6/76	6.1	Data Collection
	X		X		7/76	1.2	Data Collection
	X	X			7/76	6.8	Data Collection
	X	X			7/76	1.2	Data Collection
	X		X		8/76	4.0	Prototype Testing
	X		X		8/76	1.1	Prototype Testing
						22.2	

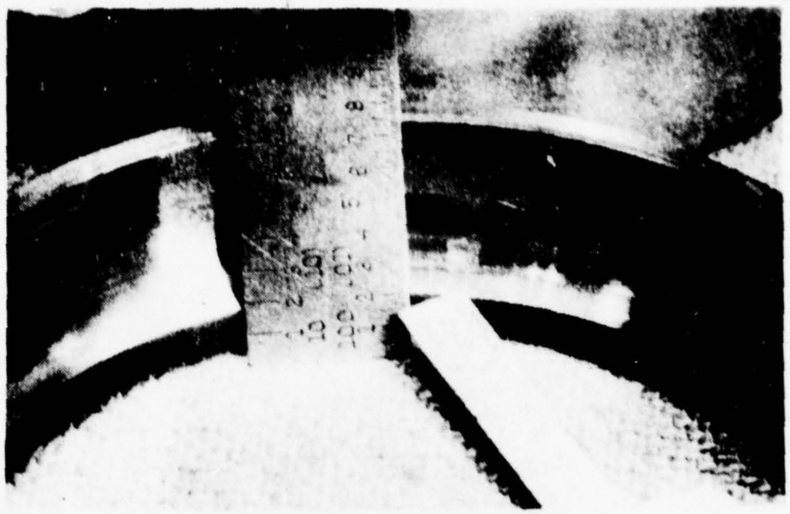

Figure E-3
Implant BHC-003
Ball Bearing P/N 204-040-143, S/N 53628
Natural Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		3/74	1.7	Part Validation
X			X		3/74	2.0	Part Validation
	X		X		6/74	5.3	Data Collection
	X		X		6/74	1.3	Data Collection
						10.3	Total Time

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Figure E-4
Implant BHC-004
42-Degree Gearbox Pinion P/N 204-040-500-9, S/N B13-4457
Natural Category "C" Score (All Teeth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		3/74	1.8	Part Validation
	X		X		7/74	5.6	Data Collection
	X		X		7/74	5.1	Data Collection
						12.5	Total Time

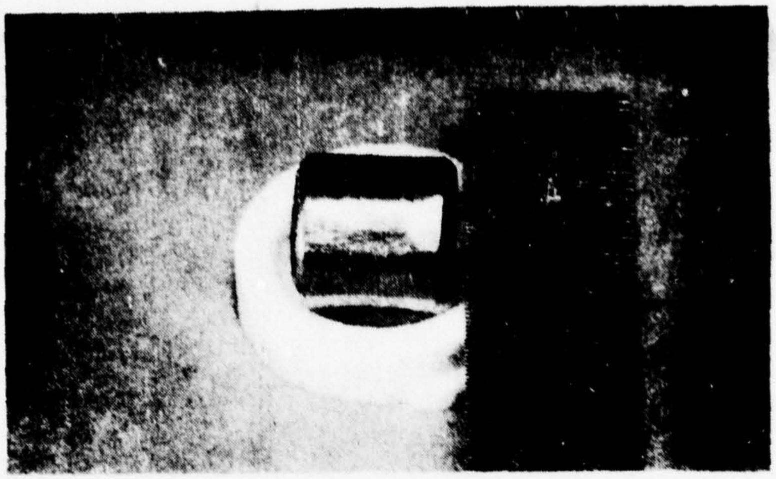

Figure E-5
Implant BHC-005
Roller Bearing P/N 204-040-310, S/N 150848
Artificial Category "C" Roller

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		3/74	2.1	Part Validation Brg. damaged beyond repair upon removal
						2.1	Total Time

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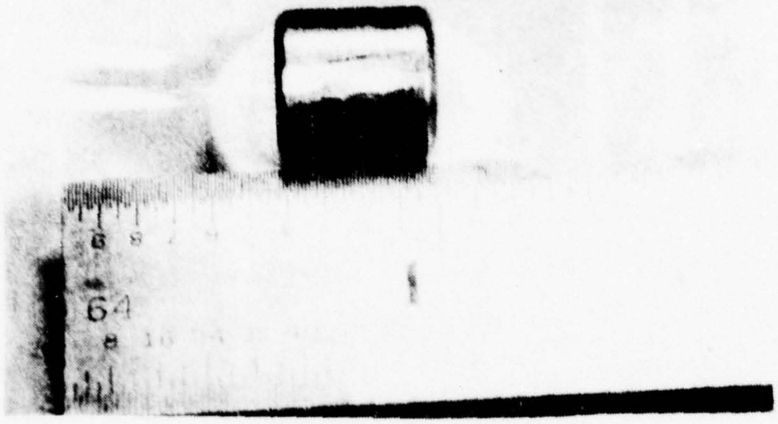

Figure E-6
Implant BHC-006
Roller Bearing P/N 204-040-310, S/N 150848
Artificial Category "C" Roller

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		3/74	2.2	Part Validation
X			X		4/74	2.0	Data Collection
	X		X		4/74	4.1	Data Collection
	X		X		7/74	6.0	Data Collection
	X		X		8/74	4.2	Data Collection
	X		X		9/74	4.4	Data Collection
	X		X		9/74	3.6	Data Collection
	X		X		12/74	10.9	Data Collection
	X		X		2/75	5.3	Data Collection
	X		X		3/75	7.2	Data Collection
	X		X		6/76	7.1	Data Collection
	X		X		7/76	1.0	Data Collection
	X		X		9/76	5.3	Data Collection
						63.3	Total Time

Figure E-7
Implant BHC-007
Ball Bearing P/N 204-040-143, S/N 4110D
Natural Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	4.2	Part Validation
	X		X		6/74	5.5	Data Collection
	X		X		7/74	4.8	Data Collection
	X		X		7/74	3.5	Data Collection
	X		X		9/74	6.7	Data Collection
	X		X		9/74	4.4	Data Collection
	X		X		10/74	3.1	Data Collection
	X		X		10/74	5.9	Data Collection
	X		X		11/74	1.5	Data Collection
	X		X		11/74	5.5	Data Collection
	X		X		12/74	4.2	Data Collection
	X		X		1/75	3.5	Data Collection
	X		X		2/75	4.1	Data Collection
	X		X		3/75	8.4	Data Collection
	X		X		6/75	3.8	Data Collection

BHC-007 Installation History (Cont'd)

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
	X		X		2/76	12.2	Prototype Testing
	X	X			3/76	4.7	Prototype Testing
	X		X		4/76	5.6	Prototype Testing
	X		X		6/76	5.5	Prototype Testing
	X		X		7/76	1.0	Prototype Testing
	X		X		7/76	8.5	Prototype Testing
	X		X		8/76	1.8	Prototype Testing
	X	X			9/76	5.6	Prototype Testing
						118.2	Total Time

Figure E-7. (Continued)

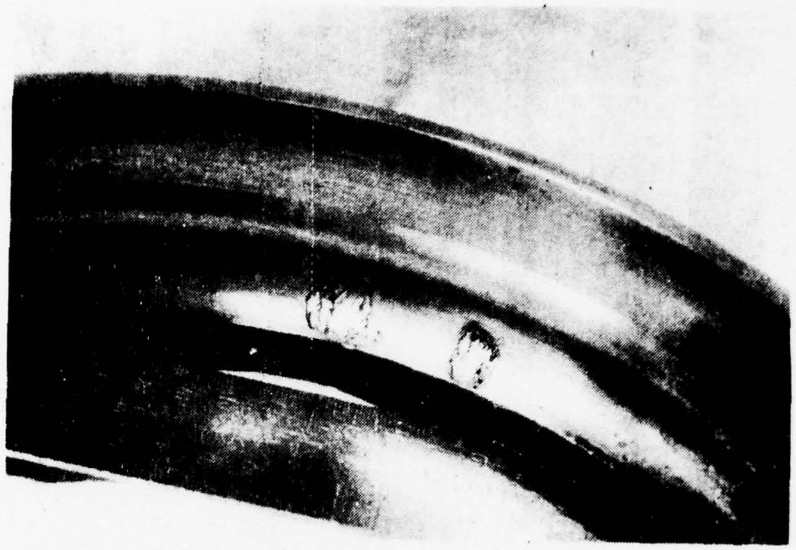

Figure E-8
Implant BHC-008
Ball Bearing P/N 204-040-143, S/N 393D
Natural Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	5/74	6.6	Part Validation
	X			X	9/74	4.0	Data Collection
	X		X		10/74	4.6	Data Collection
	X		X		1/75	3.1	Data Collection
	X		X		1/75	5.6	Data Collection
	X			X	4/75	4.4	Data Collection
	X		X		5/75	4.9	Data Collection
	X		X		6/75	3.2	Data Collection
X		X			1/76	91.8	Removal Limit Confidence Test
	X		X		3/76	4.9	Prototype Testing
	X		X		5/76	5.3	Prototype Testing
	X		X		6/76	0.8	Prototype Testing
	X	X			9/76	12.8	Prototype Testing
	X			X	10/76	8.5	Prototype Testing
						160.2	Total Time

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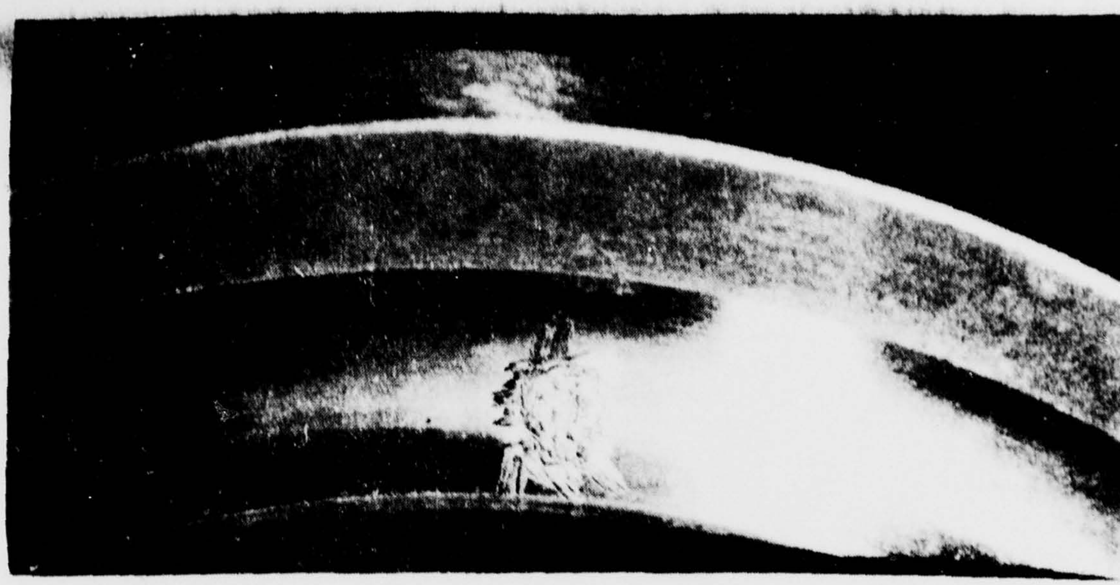

Figure E-9
Implant BHC-009
Ball Bearing P/N 204-040-143, S/N 84618
Artificial Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	0.55	Part Validation
	X		X		7/74	4.9	Data Collection
	X		X		8/74	13.4	Data Collection
	X			X	9/74	4.3	Data Collection
	X		X		1/75	6.1	Data Collection
	X			X	4/75	4.5	Data Collection
	X	X			10/76	5.2	Data Collection
						38.9	Total Time

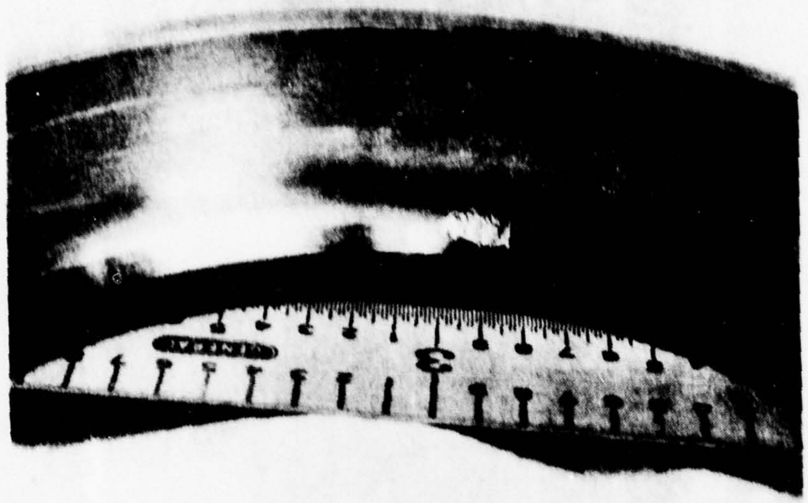

Figure E-10
Implant BHC-010
Ball Bearing P/N 204-040-143, S/N 2503
Artificial Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	0.7	Part Validation
	X		X		6/74	3.5	Part Validation
	X	X			6/74	5.7	Part Validation
	X		X		8/74	10.1	Part Validation
	X	X			7/74	6.9	Part Validation
	X			X	8/74	3.7	Part Validation
	X	X			8/74	0.8	Part Validation
	X			X	8/76	6.6	Data Collection
	X		X		10/76	8.5	Data Collection
						46.5	Total Time

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Figure E-11
Implant BHC-011
Ball Bearing P/N 204-040-143, S/N 1472C
Artificial Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	0.5	Part Validation
	X	X			8/74	3.2	Data Collection
	X	X			8/74	3.7	Data Collection
	X	X			9/74	3.2	Data Collection
	X		X		1/75	6.6	Data Collection
	X		X		11/76	5.0	Data Collection
						22.2	Total Time

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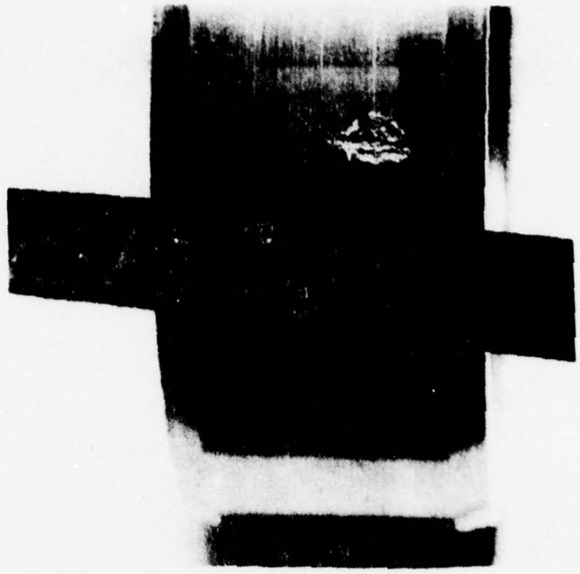

Figure E-12
Implant BHC-012
Roller Bearing P/N 204-040-310, S/N 154519
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	0.6	Part Validation
	X		X		6/74	3.4	Data Collection
	X		X		8/74	7.9	Data Collection
	X	X			5/76	4.3	Data Collection
	X	X			6/76	2.3	Data Collection
						18.5	Total Time

Figure E-13
Implant BHC-013
Roller Bearing P/N 204-040-310, S/N H1660
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	0.5	Part Validation
	X		X		7/74	6.2	Data Collection
	X		X		7/74	4.5	Data Collection
	X	X			8/74	3.2	Data Collection
	X	X			9/74	4.0	Data Collection
	X		X		5/76	5.8	Data Collection
	X		X		6/76	1.0	Data Collection
	X	X			6/76	5.7	Data Collection
	X	X			7/76	0.9	Data Collection
						31.8	Total Time

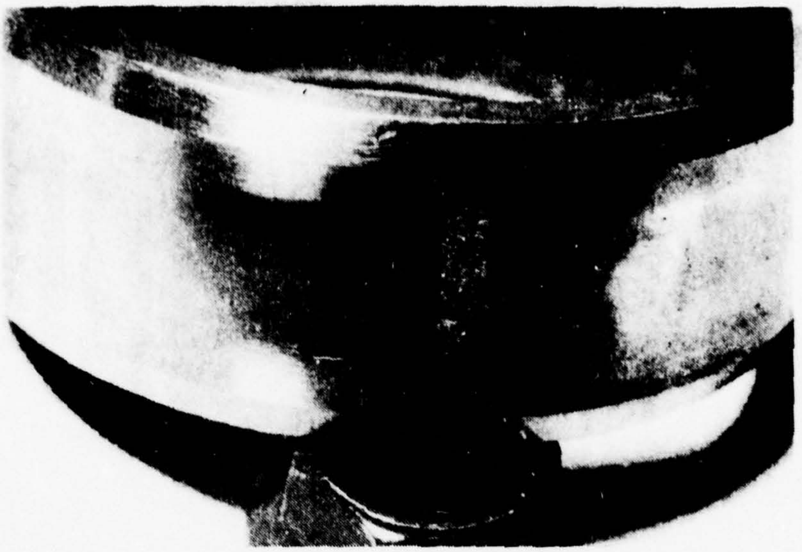

Figure E-14
Implant BHC-014
Roller Bearing P/N 204-040-310, S/N 146762
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	1.3	Part Validation
	X		X		8/74	5.5	Data Collection
	X	X			9/74	5.0	Data Collection
	X		X		5/75	4.5	Data Collection
	X		X		6/75	3.2	Data Collection
					11/76	8.5	Data Collection
						31.6	Total Time

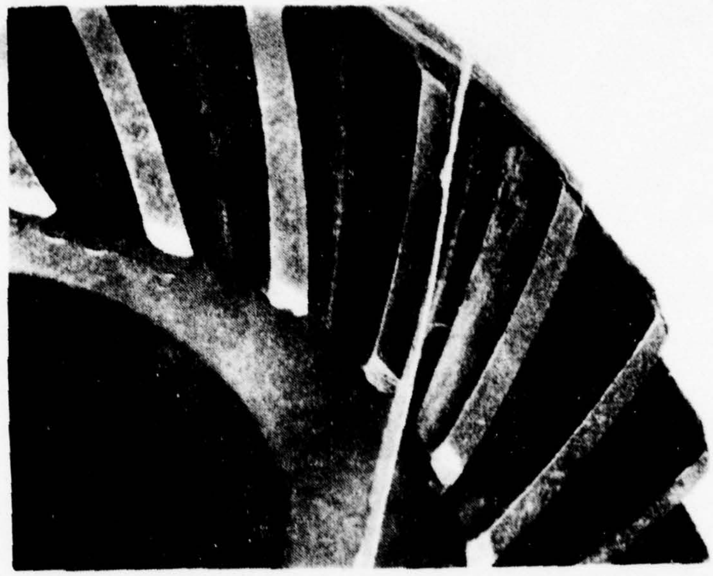

Figure E-15
Implant BHC-015
42-Degree Gearbox Pinion P/N 204-040-500-9, S/N A13-2547
Artificial Category "C" Score (All Teeth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	1.2	Part Validation
	X		X		1/75	5.0	Data Collection
	X		X		10/76	5.9	Data Collection
						12.1	Total Time

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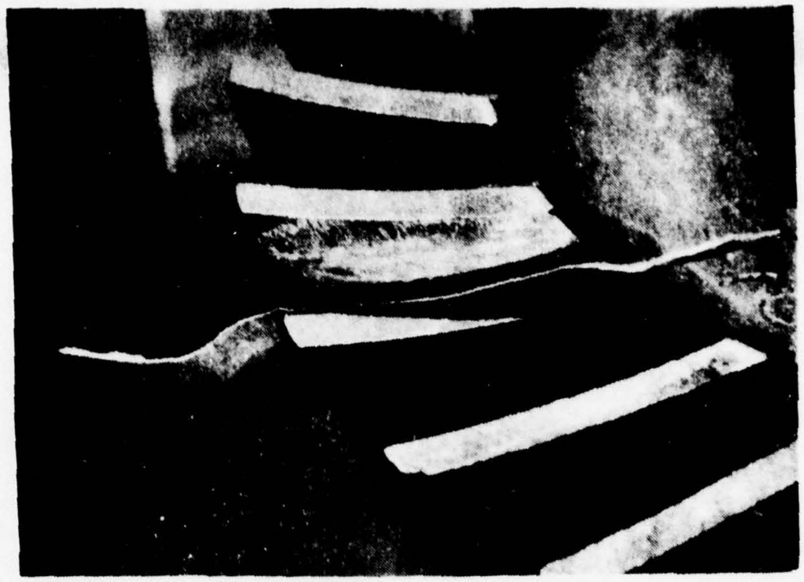

Figure E-16
Implant BHC-016
42-Degree Gearbox Gear P/N 204-040-500-10, S/N A13-11174
Natural Category "C" Score (All Teeth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	3.8	Part Validation
	X		X		7/74	2.1	Data Collection
	X		X			5.9	Prototype Testing
						11.8	Total Time

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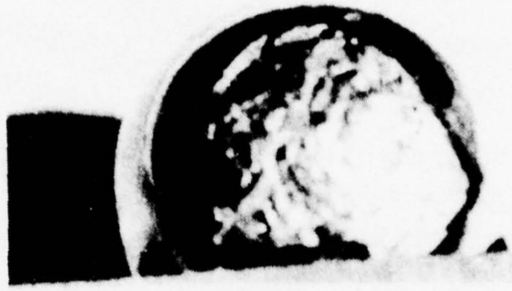

Figure E-18
Implant BHC-018
Ball Bearing P/N 204-040-143, S/N 5084
Natural Category "D" Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	0.7	Part Validation
	X		X		7/74	3.2	Data Collection
	X		X		8/74	10.3	Data Collection
	X			X	10/74	2.2	"Failed"
						16.4	Total Time

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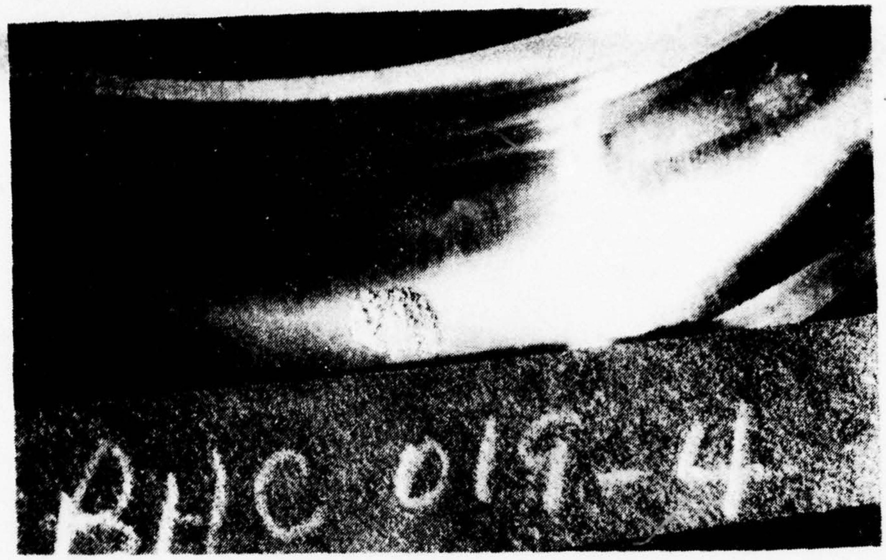

Figure E-19
Implant BHC-019
Ball Bearing P/N 204-040-143, S/N 9690
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	0.6	Part Validation
	X		X		7/74	5.9	Data Collection
	X	X			8/74	3.2	Data Collection
	X			X	9/74	3.2	Data Collection
	X			X	1/75	3.7	Data Collection
	X		X		9/76	5.3	Prototype Testing
						21.9	Total Time

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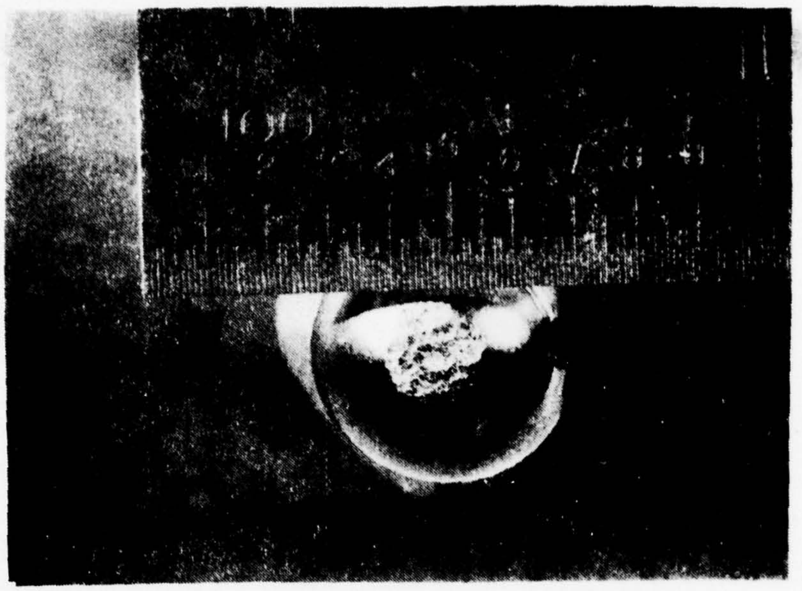

Figure E-20
Implant BHC-020
Ball Bearing P/N 204-040-143, S/N 9690
Artificial Category "C" Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	0.6	Part Validation
	X	X			8/74	3.2	Data Collection
	X		X		10/74	4.4	Data Collection
	X			X	11/74	9.1	Data Collection
	X		X		7/76	5.2	Data Collection
	X		X		7/76	0.8	Data Collection
						23.3	Total Time

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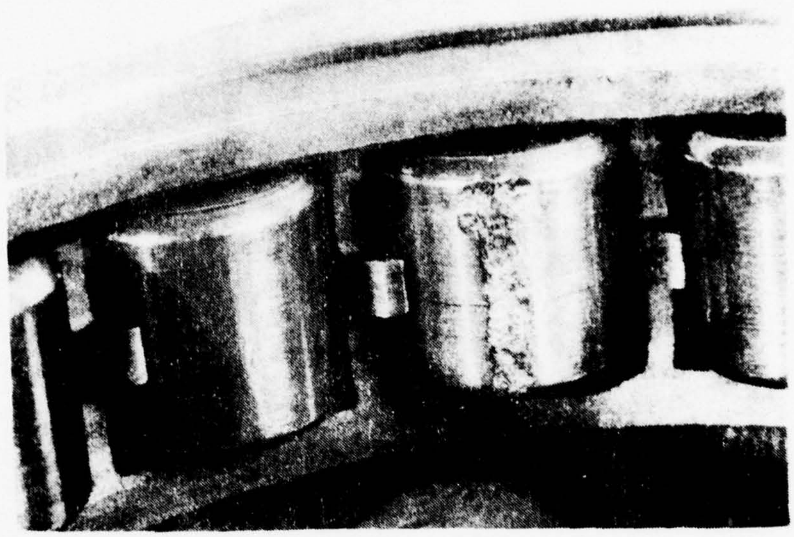

Figure E-21
Implant BHC-021
Roller Bearing P/N 204-040-310, S/N 160060
Artificial Category "C" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		6/74	0.9	Part Validation
	X	X			8/74	3.2	Data Collection
	X	X			9/74	4.3	Data Collection
	X		X		10/74	3.8	Data Collection
	X		X		11/74	6.2	Data Collection
	X		X		9/76	5.8	Prototype Testing
						24.2	Total Time

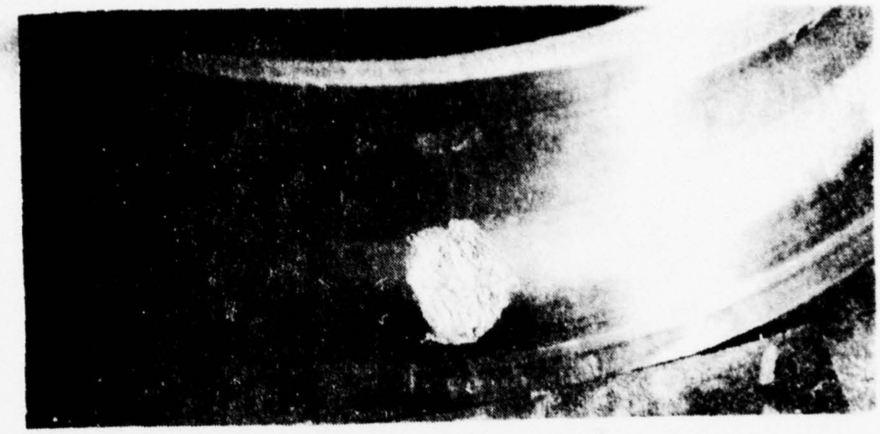

Figure E-22
Implant BHC-022
Ball Bearing P/N 204-040-143, S/N 17508
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X		X		8/74	3.2	Part Validation
	X			X	6/76	6.8	Data Collection
	X			X	7/76	2.3	Data Collection
						12.3	Total Time

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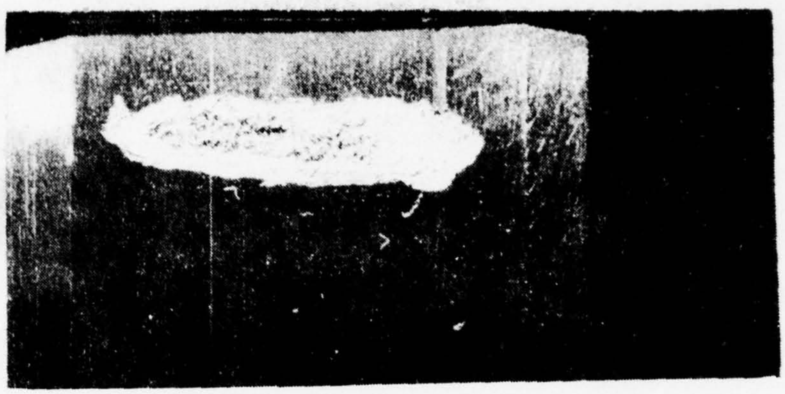

Figure E-23
Implant BHC-023
Roller Bearing P/N 204-040-310, S/N 142000
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X		X		9/74	3.2	Part Validation
	X		X		6/76	6.1	Data Collection
	X		X		7/76	1.5	Data Collection
	X	X			7/76	5.6	Data Collection
	X	X			7/76	1.7	Data Collection
						18.1	Total Time

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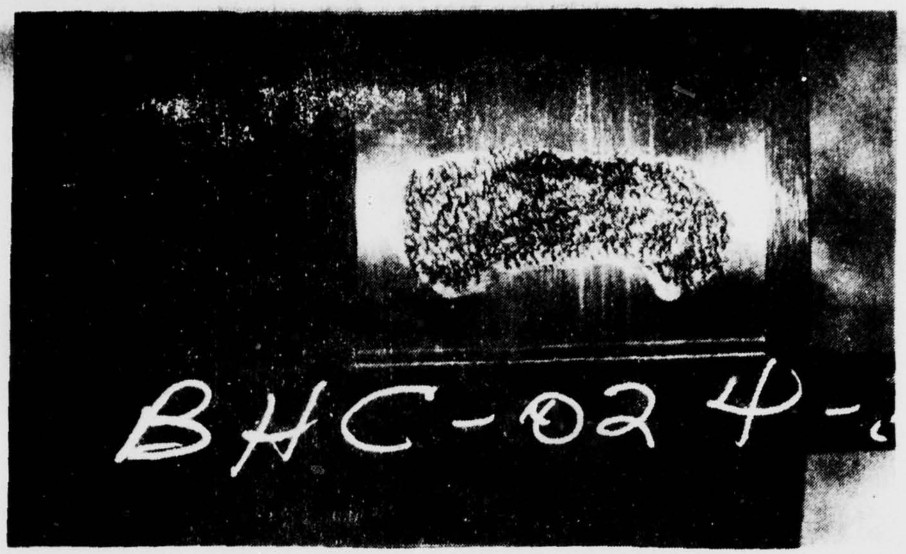

Figure E-24
Implant BHC-024
Roller Bearing P/N 204-040-310, S/N L31005
Artificial Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
	X	X			10/74	2.8	Part Validation
	X	X			11/74	3.2	Data Collection
	X		X		4/75	3.8	Data Collection
	X		X		5/75	2.6	Data Collection
	X		X		4/76	3.1	Data Collection
	X		X		7/76	5.0	Data Collection
	X		X		8/76	3.0	Data Collection
	X		X		10/76	5.7	Prototype Testing
						29.2	Total Time

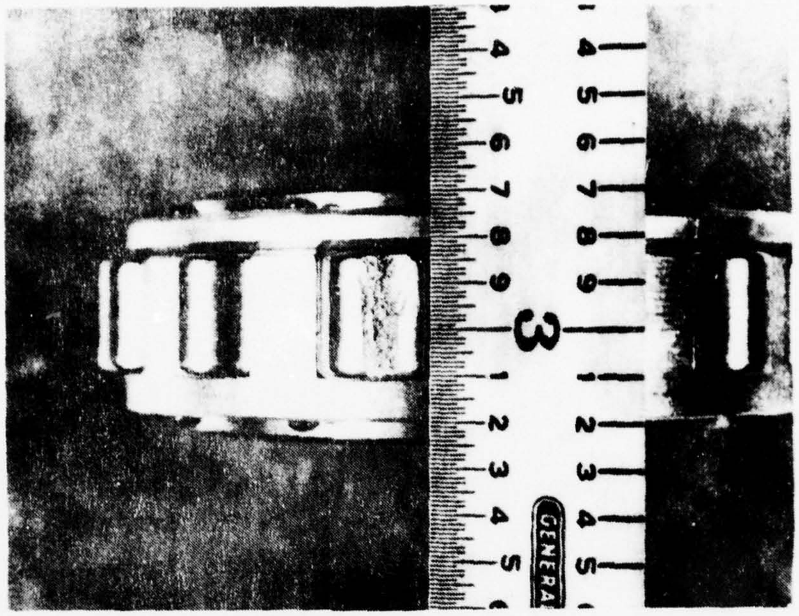

Figure E-25
Implant BHC-025
Roller Bearing P/N 204-040-406, S/N 3598
Artificial Category "C" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X				X	8/74	3.4	Part Validation
	X			X	11/74	3.2	Data Collection
	X			X	1/75	5.6	Data Collection
	X			X	3/76	6.2	Data Collection
	X			X	6/76	7.3	Data Collection
	X			X	6/76	1.0	Data Collection
	X			X	6/76	3.9	Data Collection
	X			X	8/76	0.8	Data Collection
						31.4	Total Time

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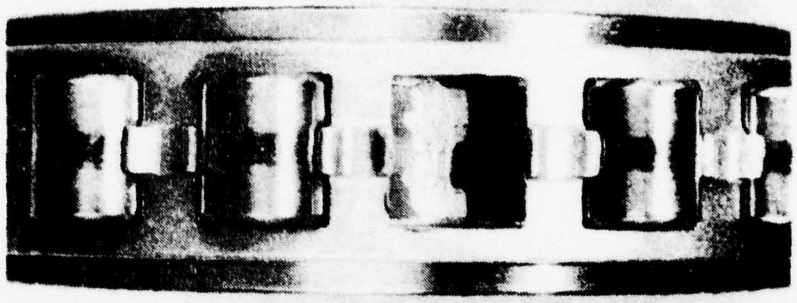

Figure E-26
Implant BHC-026
Roller Bearing P/N 204-040-407, S/N 3598
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test Cell	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	8/74	3.4	Part Validation
	X			X	10/74	2.8	Data Collection
	X			X	1/75	3.3	Data Collection
	X			X	6/76	5.7	Data Collection
	X			X	7/76	1.0	Data Collection
						16.2	Total Time

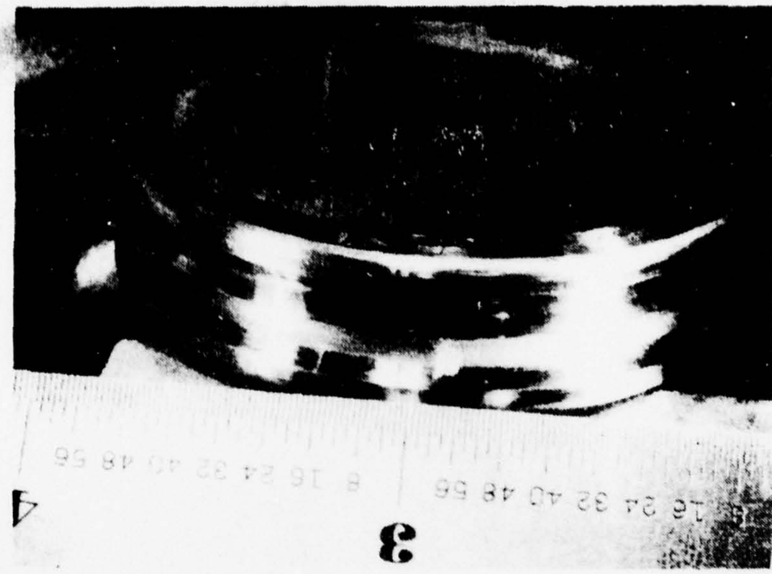

Figure E-27
Implant BHC-027
Ball Bearing P/N 204-040-424, S/N 37613
Artificial Category "C" Inner Race Pitting

Installation History

BHT Test Cell	ADTA Test Cell	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
X				X	8/74	3.4	Part Validation
	X			X	11/74	2.6	Data Collection
	X			X	2/75	4.9	Data Collection
	X			X	2/75	3.9	Data Collection
	X			X	6/76	6.4	Data Collection
	X			X	7/76	1.2	Data Collection
						22.4	Total Time

Figure E-28
Implant BHC-028
90-Degree Gearbox Gear P/N 204-040-401, S/N B13-18250
Natural Category "C" Score (All Teeth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	9/74	3.4	Part Validation
	X			X	10/74	3.1	Data Collection
						6.5	Total Time

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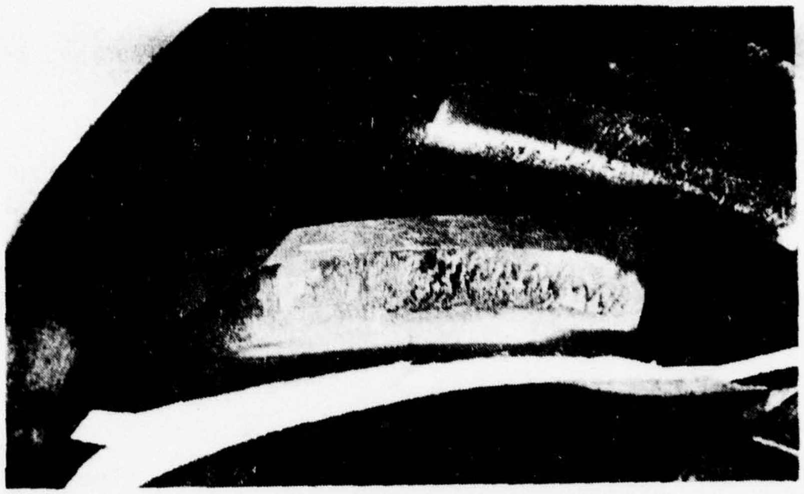

Figure E-29
Implant BHC-029
90-Degree Gearbox Pinion P/N 204-040-400, S/N A13-9566
Natural Category "C" Score (All Teeth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	9/74	3.4	Part Validation
	X			X	10/74	3.1	Data Collection
						6.5	Total Time

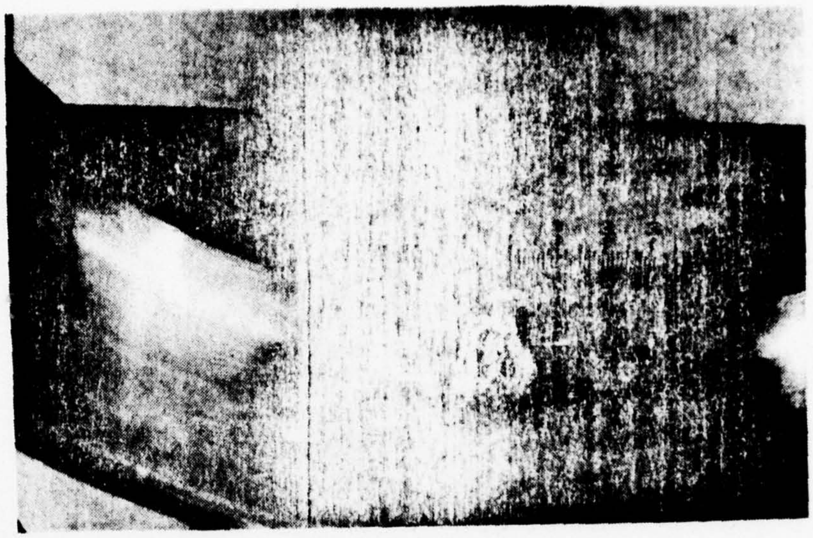

Figure E-30
Implant BHC-030
Ball Bearing P/N 204-040-143, S/N 38806
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	8/74	3.4	Part Validation
						3.4	Total Time

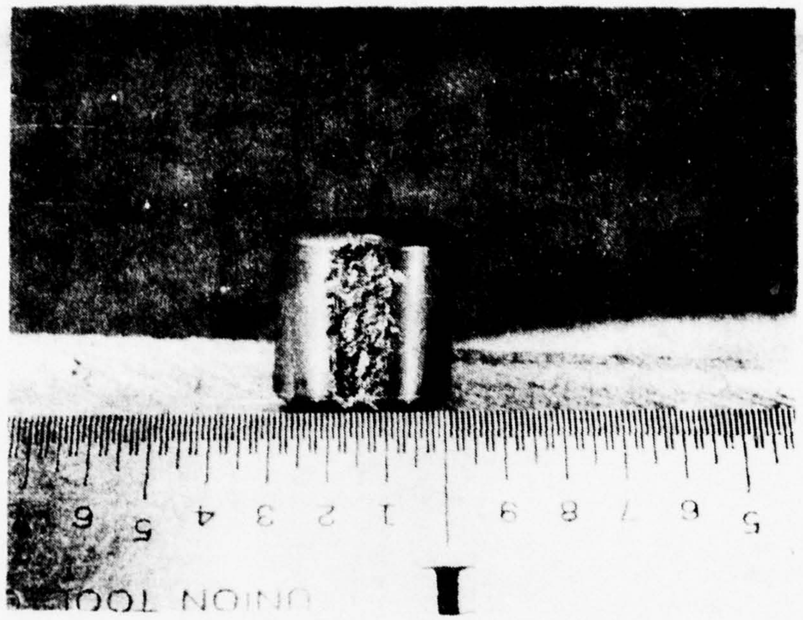

Figure E-31
Implant BHC-031
Roller Bearing P/N 204-040-407, S/N 8022
Artificial Category "C" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X				X	8/74	3.4	Part Validation
	X			X	7/76	4.9	Data Collection
	X			X	7/76	1.0	Data Collection
						9.3	Total Time

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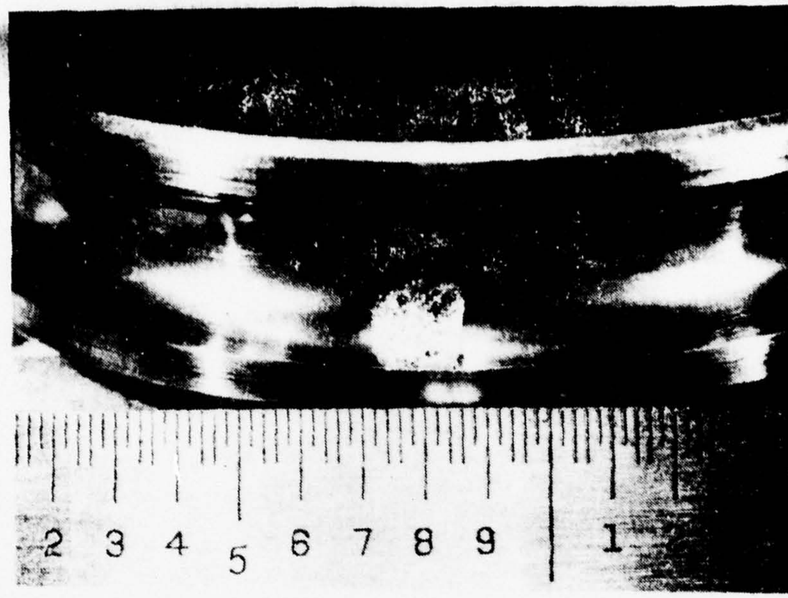

Figure E-32
Implant BHC-032
Ball Bearing P/N 204-040-424, S/N 9494
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
X				X	8/74	3.4	Part Validation
	X			X	7/76	4.7	Data Collection
	X			X	7/76	1.8	Data Collection
						9.9	Total Time

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Figure E-33
Implant BHC-033
90-Degree Gearbox Pinion P/N 204-040-400, S/N A13-4765
Natural Category "C" Score (Every Third Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	9/74	3.4	Part Validation
	X			X	11/74	4.2	Data Collection
X				X	3/76	43.9	Removal Limit Confidence Test
						51.5	Total Time

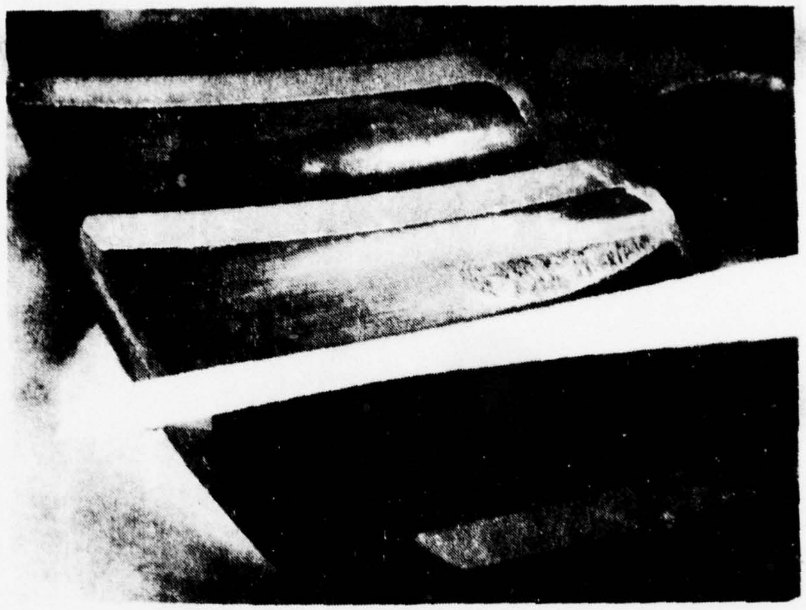

Figure E-34
Implant BHC-034
90-Degree Gearbox Gear P/N 204-040-401, S/N A13-6296
Natural Category "C" Score (Every Third Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	9/74	3.4	Part Validation
	X			X	11/74	4.2	Data Collection
X				X	3/76	43.9	Removal Limit Confidence Test
						51.5	Total Time

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Figure E-35
Implant BHC-035
Roller Bearing P/N 204-040-406, S/N 23431
Artificial Category "C" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	8/74	3.4	Part Validation
	X			X	6/76	4.2	Data Collection
	X			X	7/76	1.5	Data Collection
	X			X	9/76	6.3	Prototype Testing
						15.4	Total Time

Figure E-36
Implant BHC-036
Transmission Input Pinion, P/N 204-040-700, S/N F12-492
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			10/74	6.4	Part Validation
	X	X			12/74	3.5	Data Collection
	X	X			6/75	3.3	Data Collection
X	X				2/76	90.1	Removal Limit Confidence Test
	X	X			5/76	6.4	Prototype Testing
	X	X			7/76	1.0	Prototype Testing
	X	X			10/76	8.5	Prototype Testing
						119.3	Total Time

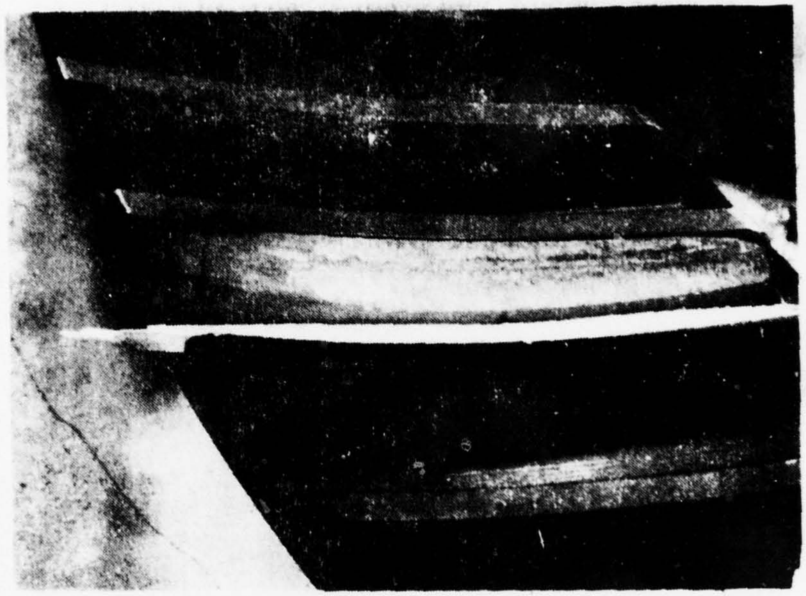

Figure E-37
Implant BHC-037
Transmission Input Gear, P/N 204-040-701, S/N A12-12910
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			10/74	6.4	Part Validation
	X	X			12/74	3.5	Data Collection
	X	X			6/75	3.3	Data Collection
X	X				2/76	90.1	Removal Limit Confidence Test "Failed"
						103.3	Total Time

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AUTOMATIC INSPECTION, DIAGNOSTIC AND PROGNOSTIC SYSTEM (AIDAPS)--ETC(U)
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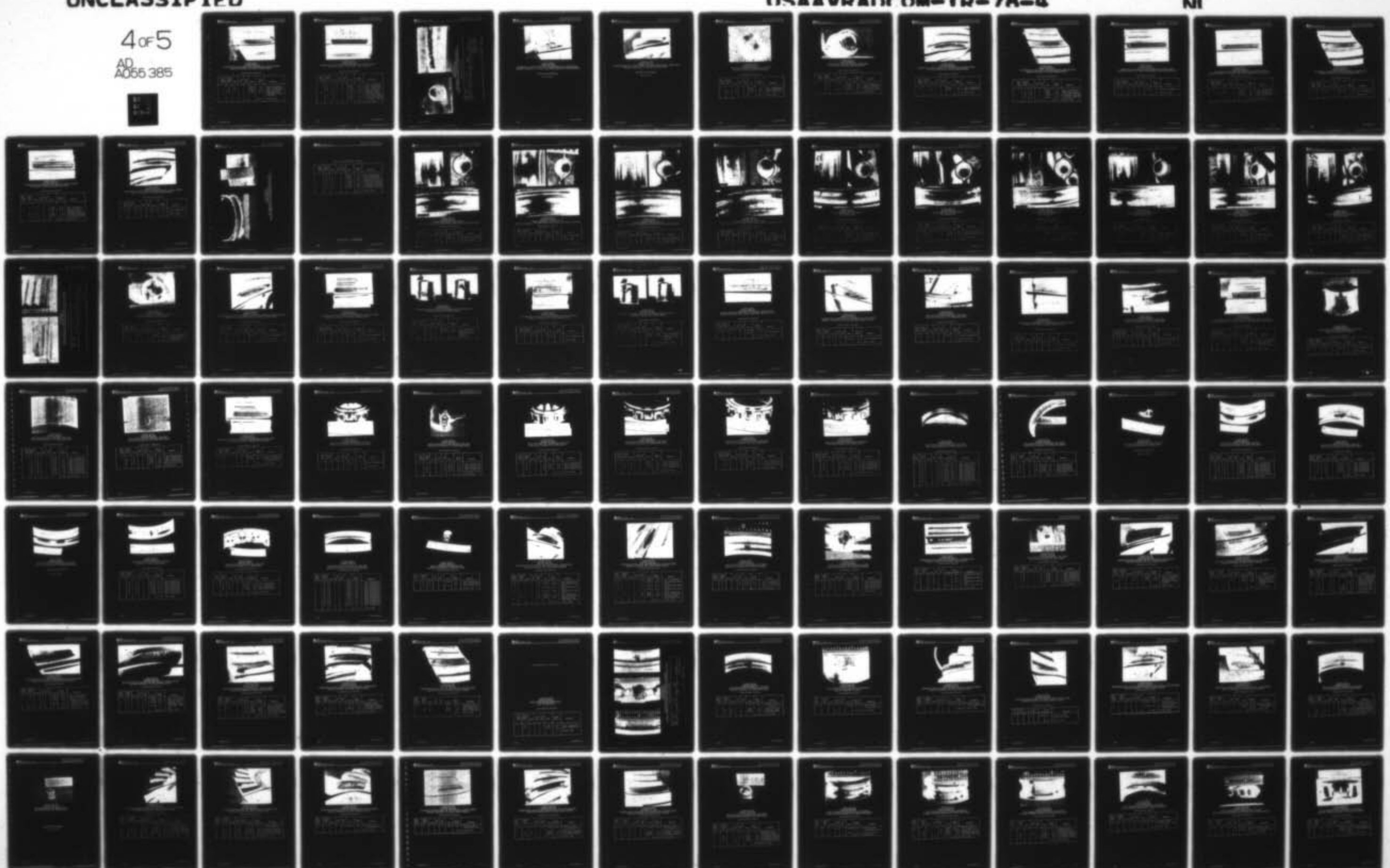

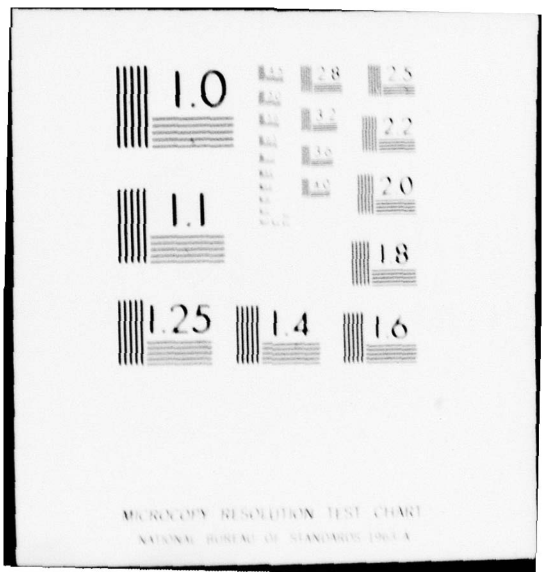
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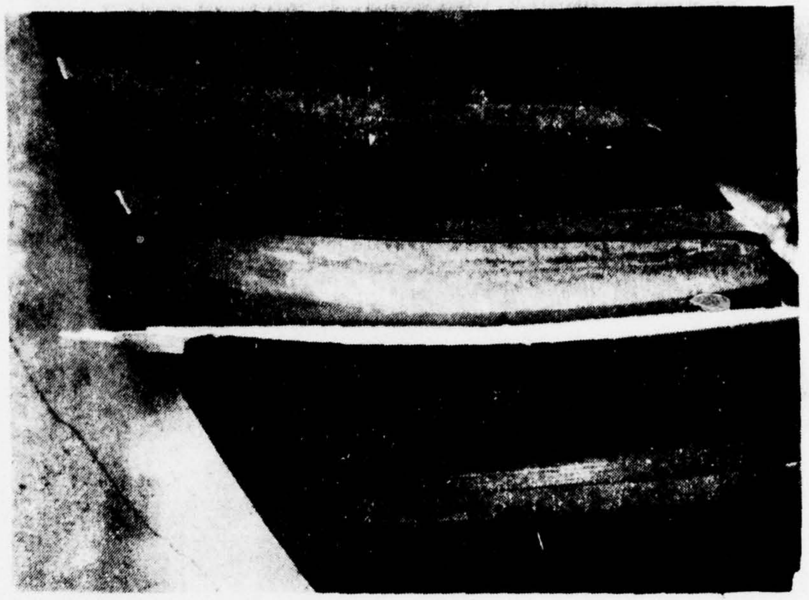

Figure E-37
Implant BHC-037
Transmission Input Gear, P/N 204-040-701, S/N A12-12910
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			10/74	6.4	Part Validation
	X	X			12/74	3.5	Data Collection
	X	X			6/75	3.3	Data Collection
X	X				2/76	90.1	Removal Limit Confidence Test "Failed"
						103.3	Total Time

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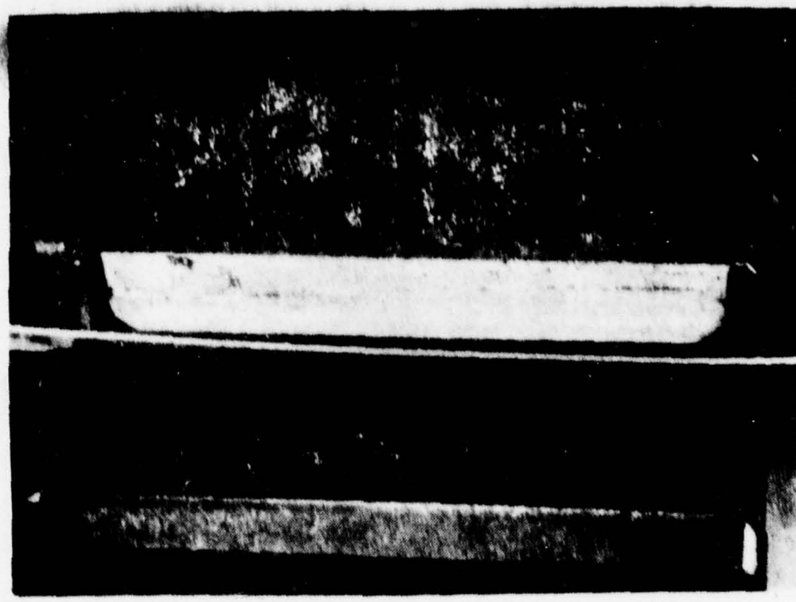
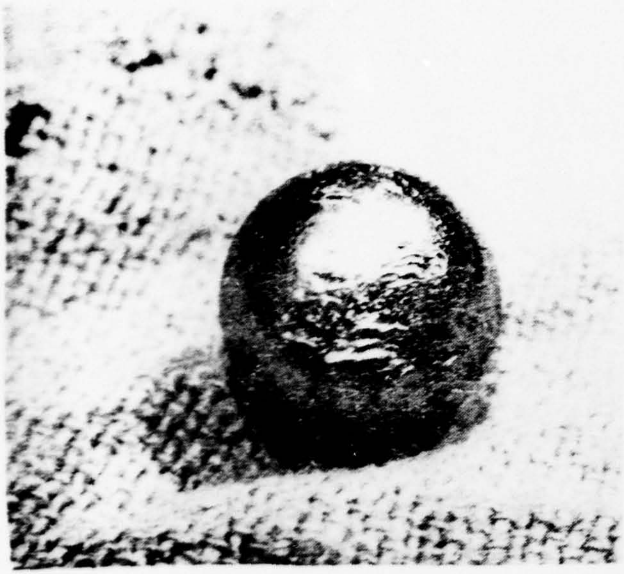


Figure E-38
Implant BHC-038
Transmission Sun Gear, P/N 204-040-330, S/N A12-12375
Natural Category "D" Spall (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			11/74	2.6	Part Validation
	X	X			11/74	3.9	Data Collection
	X	X			1/75	4.5	Data Collection
	X	X			2/75	3.4	Data Collection
X		X			1/76	91.8	Removal Limit Confidence Test
	X	X			5/76	5.5	Prototype Testing
		X			6/76	0.9	Prototype Testing
	X	X			9/76	5.3	Prototype Testing
						117.9	Total Time



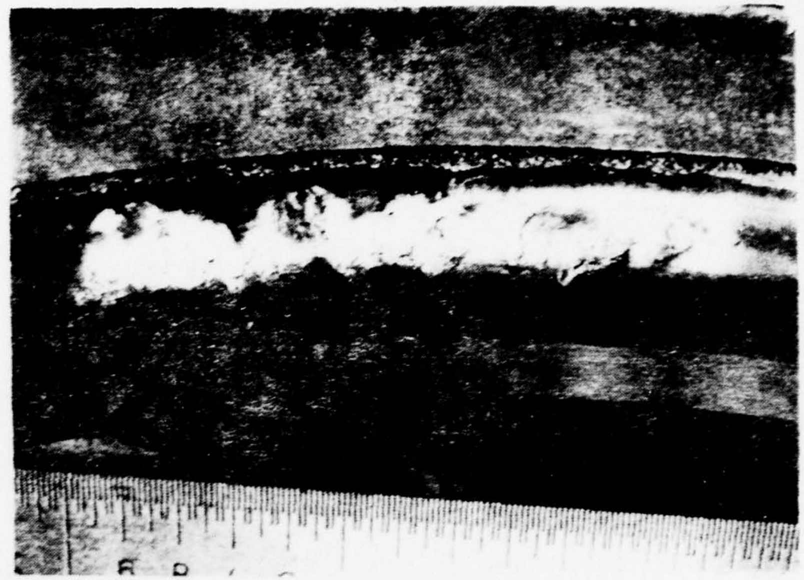


Figure E-39
Implant BHC- 039
Ball Bearing P/N 205-040-245, S/N 6925
Natural Category "D" Ball And Inner Race Spalls

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit Confidence Test Failed-IR Spun On Shaft
						91.8	Total Time

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Figure E-40
Implant BHC-040
Transmission, Sump Quill Gear P/N 204-040-103, S/N F12-2237
Natural Category "D" Tooth Chip (One) And Score (Every Tooth)

Installation History

Never Used.

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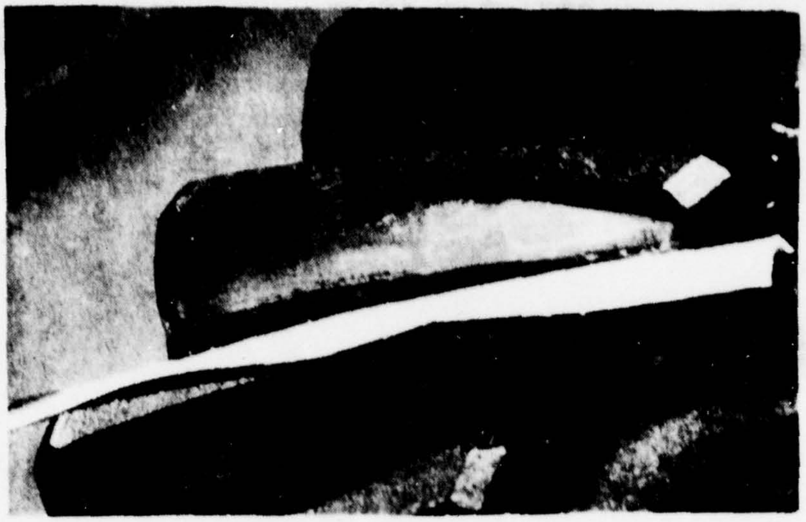

Figure E-41
Implant BHC-041
Transmission Tail Rotor Output Gear P/N 204-040-104, S/NB12-8031
Natural Category "D" Scoring (Every Tooth)

Installation History

Never Used.

Figure E-42
Implant BHC-042
Ball Bearing P/N 205-040-245, S/N 1306
Natural Category "C" Ball Pitting

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
	X	X			2/75	8.8	Data Collection
	X	X			3/75	8.0	Data Collection
						18.6	Total Time

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Figure E-43
Implant BHC-043
Ball Bearing P/N 204-040-143, S/N 47444
Artificial Category "D" Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X		X		12/75	4.8	Part Validation
	X			X	5/76	4.3	Data Collection
	X			X	6/76	0.8	Data Collection
	X		X		10/76	5.3	Prototype Testing
						15.2	Total Time

Figure E-44
Implant BHC-044
Transmission Input Pinion P/N 204-040-700, S/N A12-13602
Natural Category "C" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
	X	X			6/75	6.2	Data Collection
						8.0	Total Time

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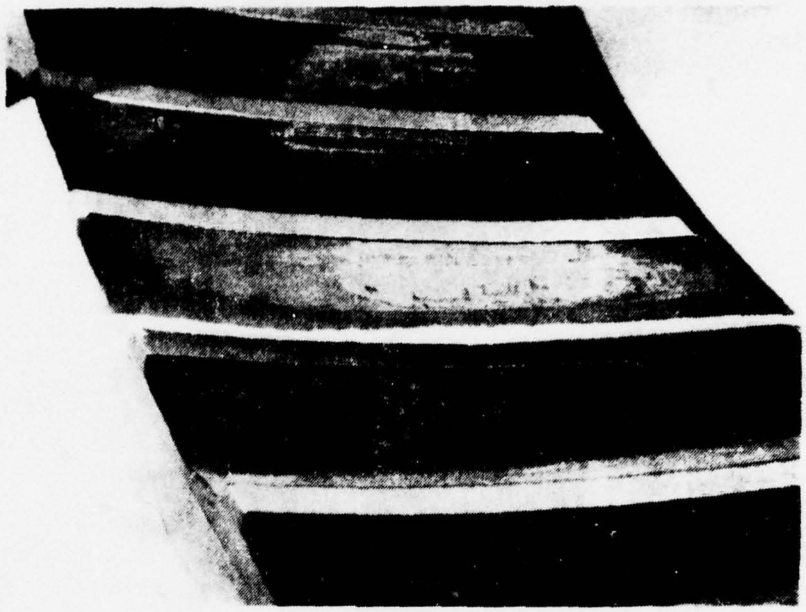

Figure E-45
Implant BHC-046
Transmission Input Gear P/N 204-040-701, S/N A12-9373
Natural Category "C" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
	X	X			6/75	6.2	Data Collection
	X	X			5/76	6.4	Prototype Testing
	X	X			7/76	1.0	Prototype Testing
	X	X			10/76	8.5	Prototype Testing
						23.9	Total Time

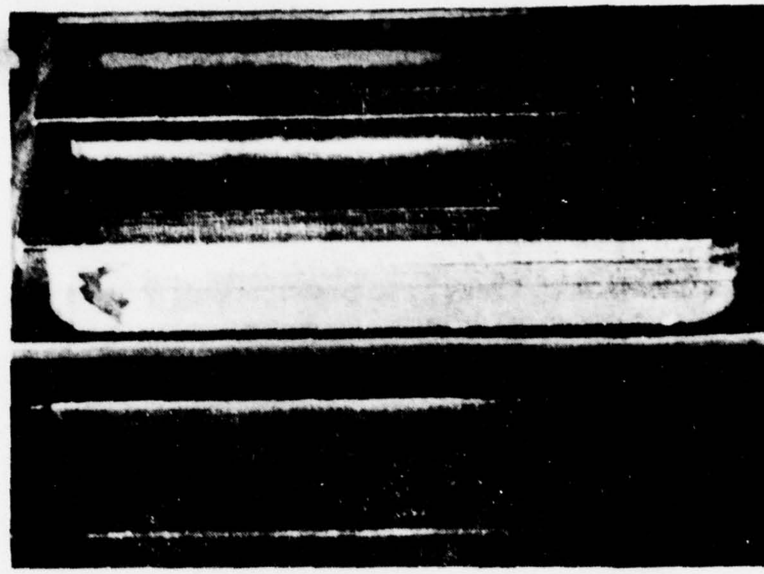

Figure E-46
Implant BHC-047
Transmission Sun Gear P/N 204-040-330, S/N B12-4323
Natural Category "B" Spall (One Tooth); Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			9/74	1.8	Part Validation
						1.8	Total Time

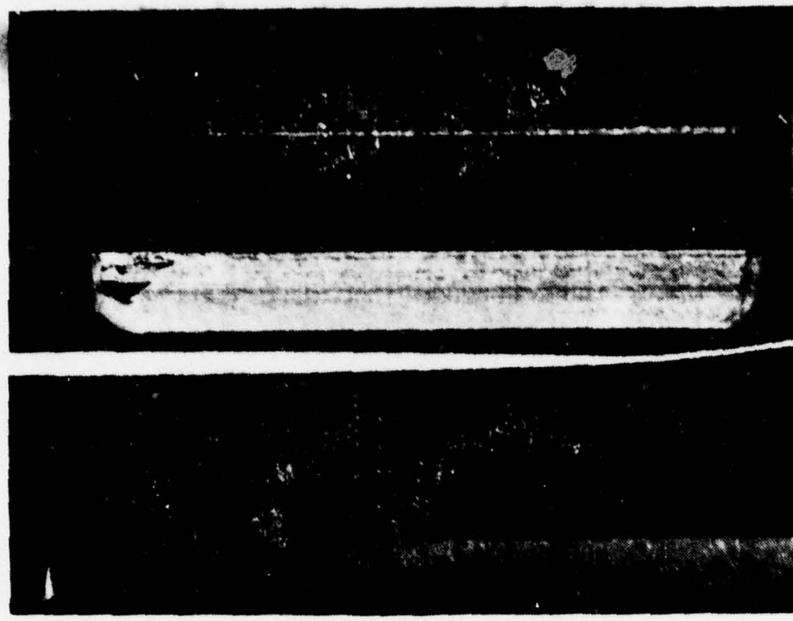

Figure E-47
Implant BHC-048
Transmission Sun Gear P/N 204-040-330, S/N F12-1494
Natural Category "C" Spall (Two Teeth) Pitting (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{O} GB	90^{O} GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
	X	X			12/74	4.2	Data Collection
	X	X			1/75	5.6	Data Collection
					4/75	4.4	Data Collection
						15.9	Total Time

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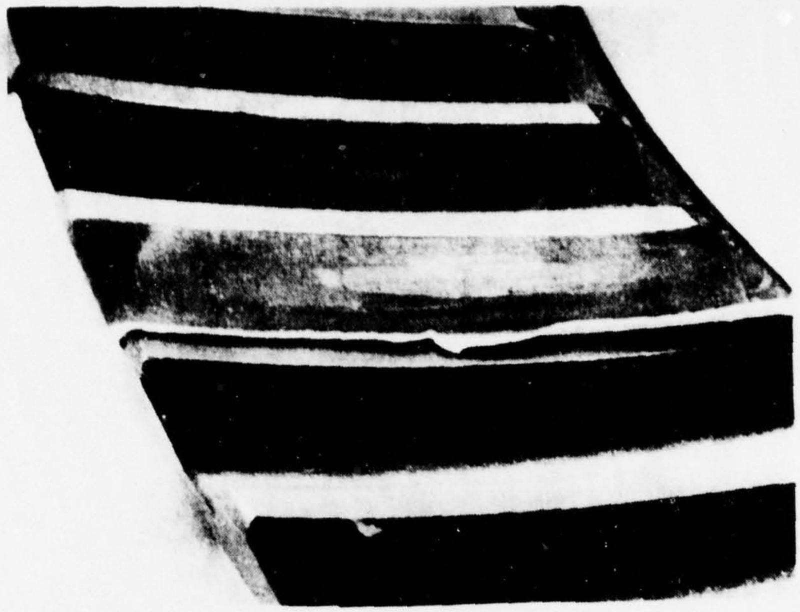

Figure E-48
Implant BHC-049
Transmission Input Gear P/N 204-040-701, S/N F12-605
Natural Category "C" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
						1.7	Total Time

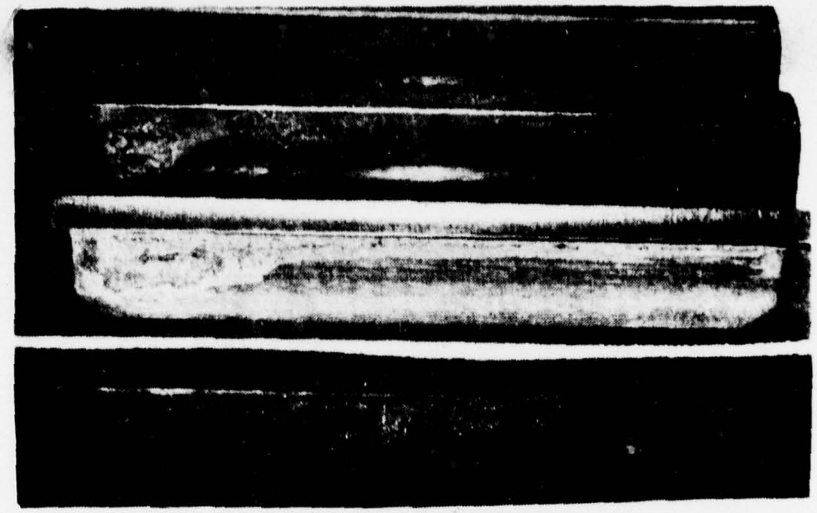

Figure E-49
Implant BHC-050
Transmission Sun Gear P/N 204-040-330, S/N A12-13458
"D" Natural Tooth Spall (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			7/75	2.4	Part Validation
X		X			2/76	90.1	Removal Limit Confidence Test
	X	X			6/76	5.2	Prototype Testing
	X	X			7/76	1.4	Prototype Testing
	X	X			10/76	5.3	Prototype Testing
						104.4	Total Time

Figure E-50
Implant BHC-051
Transmission Input Pinion P/N 204-040-700, S/N A12-14018
Natural Category "C" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
						1.7	Total Time

Figure E-51
Implant BHC-052
Ball Bearing P/N 204-040-136, S/N 1919X
Natural Category "D" Inner And Outer Race Spalls

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BHC-052 Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			10/74	3.1	Part Validation
	X	X			3/75	2.7	Data Collection
	X	X			6/75	3.2	Data Collection
	X	X			1/76	3.2	Prototype Testing
	X	X			4/76	3.3	Prototype Testing
	X	X			7/76	1.0	Prototype Testing
	X	X			8/76	2.4	Prototype Testing
	X	X			8/76	0.8	Prototype Testing
						19.7	Total Time

Figure E-51. (Continued)

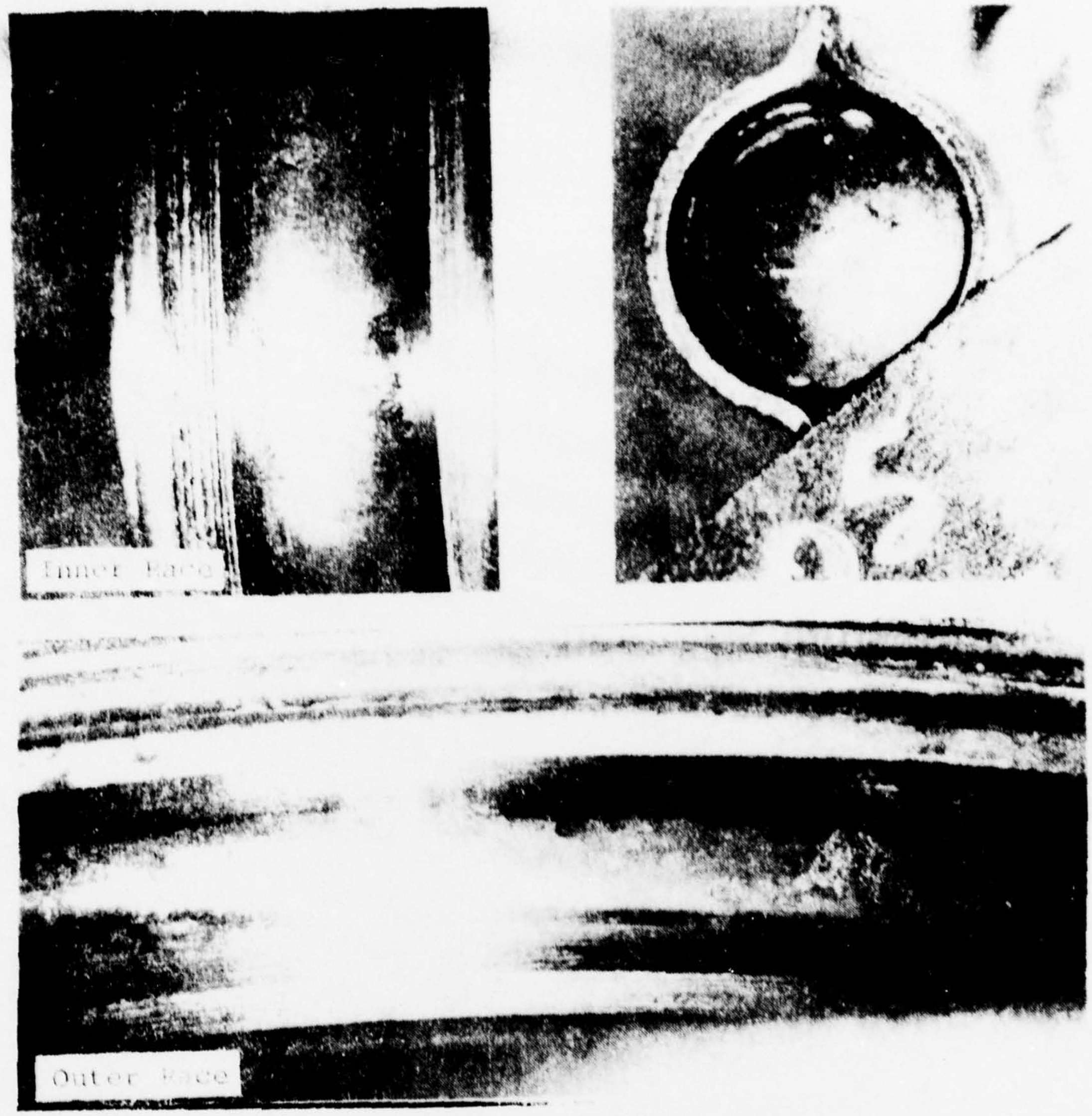

Figure E-52
Implant BHC-053
Hanger Bearing P/N 204-040-623
Natural Category "D" Inner Race, Outer Race and Ball Spalls

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
	X				3/75	0.4	Part Validation
	X				3/75	5.9	Data Collection
						6.3	Total Time

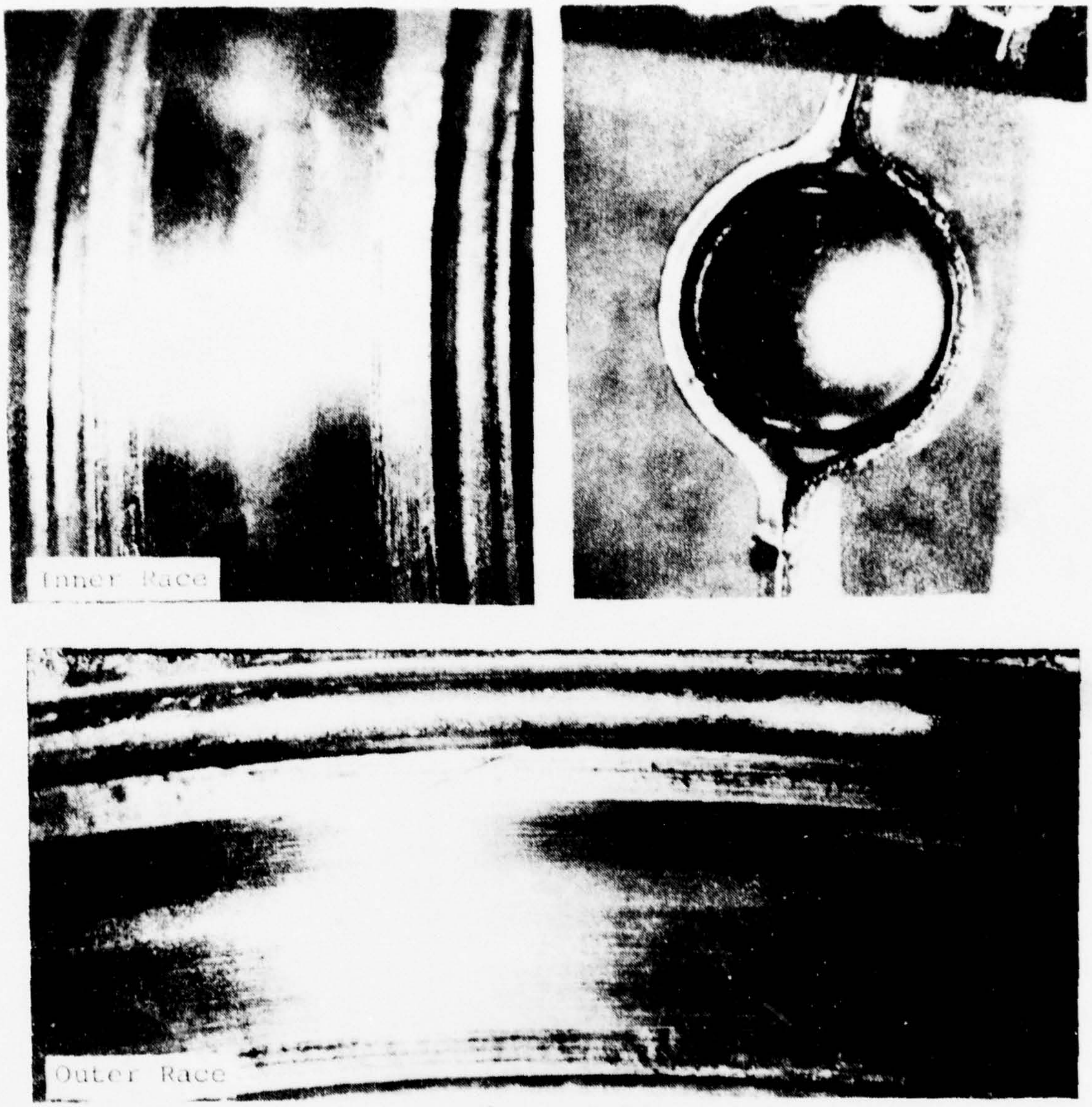

Figure E-53
Implant BHC-054
Hanger Bearing P/N 204-040-623
Natural Category "A" Inner Race, Outer Race and Ball Condition

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X				3/75	0.6	Part Validation
	X				3/75	3.0	Data Collection
						3.6	Total Time

Figure E-54
Implant BHC-055
Hanger Bearing P/N 204-040-623
Natural Category "D" Inner Race, Outer Race and Ball Spalls

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{O} GB	90^{O} GB	Date	Test Hours	Remarks
	X				3/75	0.5	Part Validation
	X				3/75	3.9	Data Collection
						4.4	Total Time

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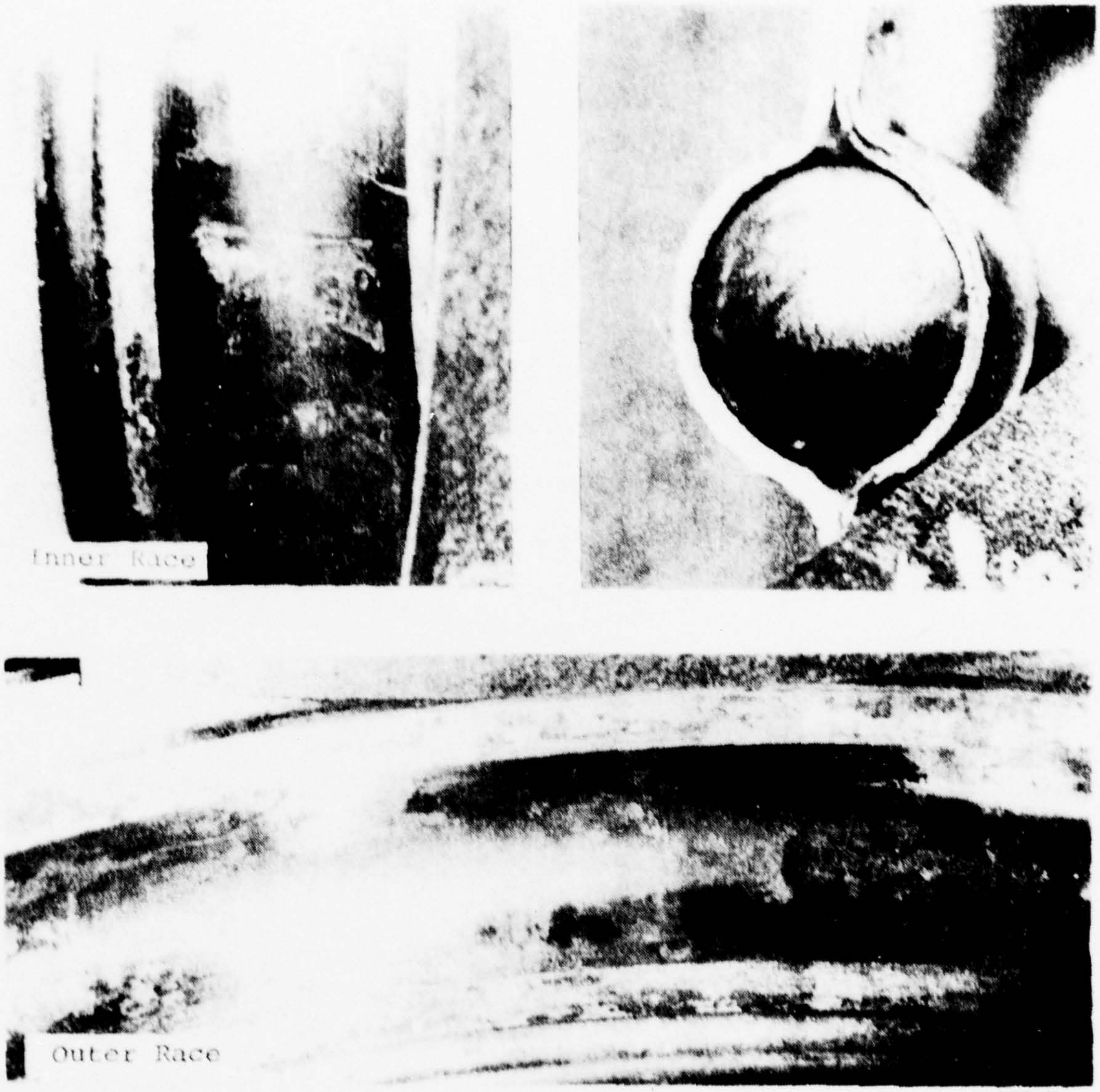

Figure E-55
Implant BHC-056
Hanger Bearing P/N 204-040-623
Natural Category "D" Inner Race, Outer Race, and Ball Spalls

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
	X				3/75	0.6	Part Validation
	X				3/75	3.0	Data Collection
						3.6	Total Time

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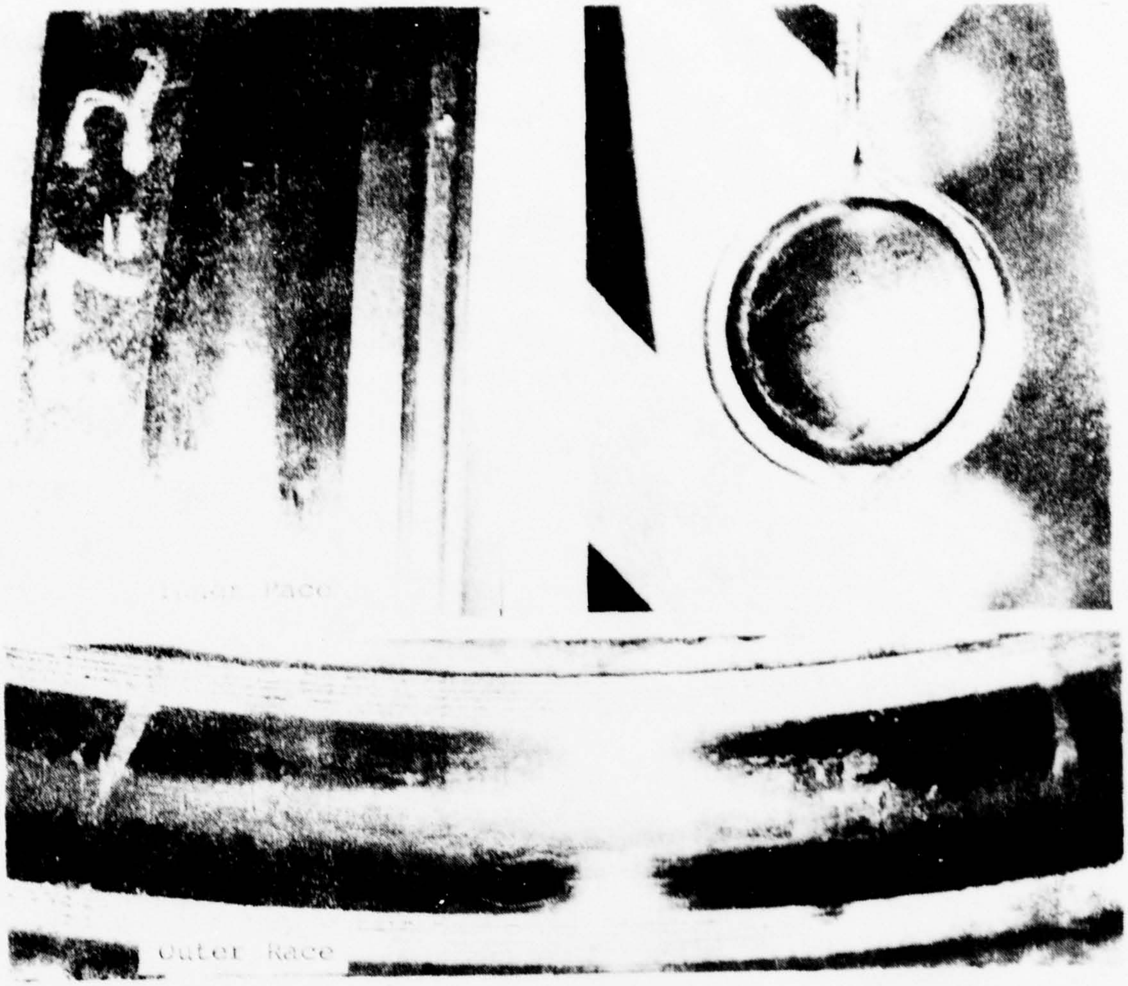

Figure E-56
Implant BHC-057
Hanger Bearing P/N 204-040-623
Not Categorized

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X				6/76	0.1	Part Validation
	X				6/76	7.2	Data Collection
	X				9/76	7.5	Data Collection
						14.8	Total Time

Figure E-57
Implant BHC-058
Hanger Bearing P/N 204-040-623
Not Categorized

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
	X				6/76	0.1	Part Validation
	X				6/76	4.9	Data Collection
						5.0	Total Time

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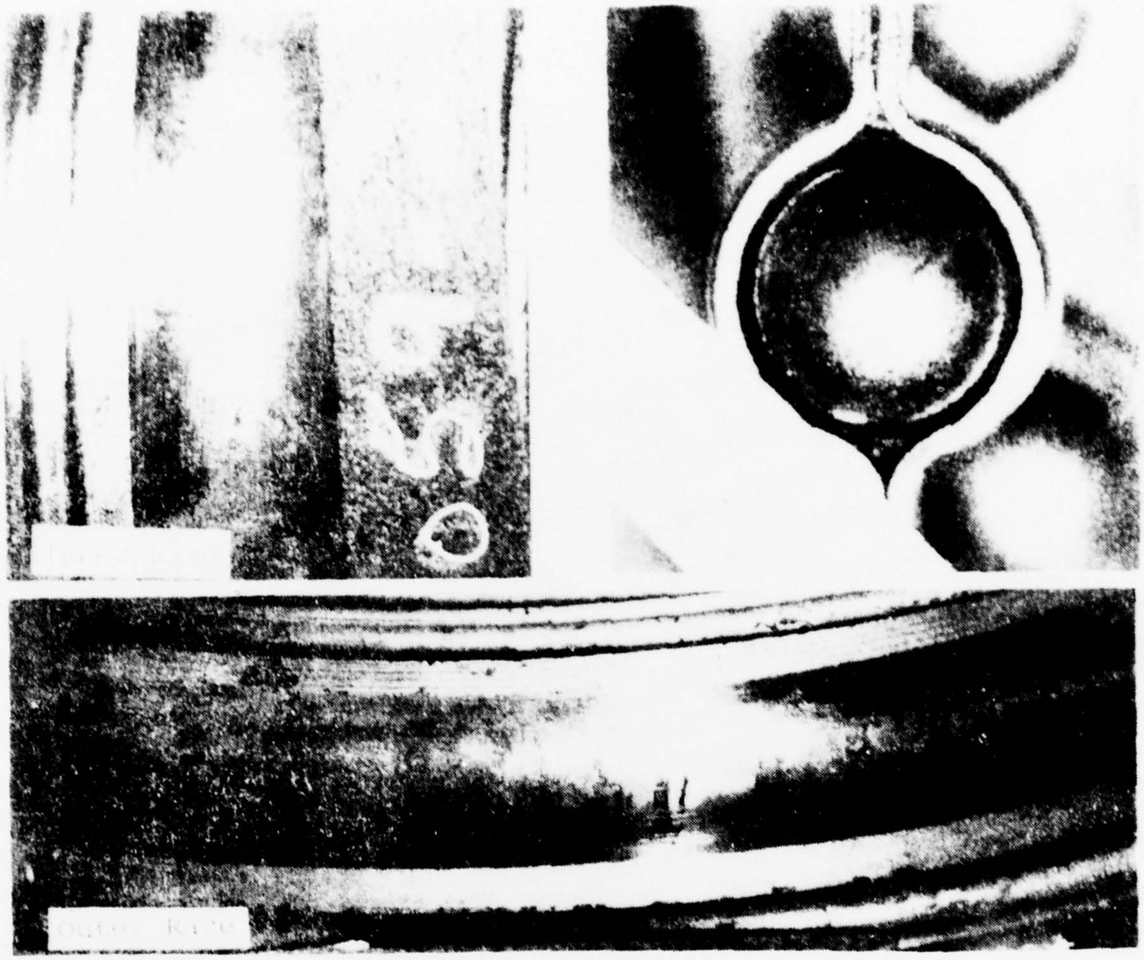

Figure E-58
Implant BHC-059
Hanger Bearing P/N 204-040-623
Not Categorized

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
	X				6/76	1.0	Part Validation
	X				6/76	3.7	Data Collection
						4.8	Total Time

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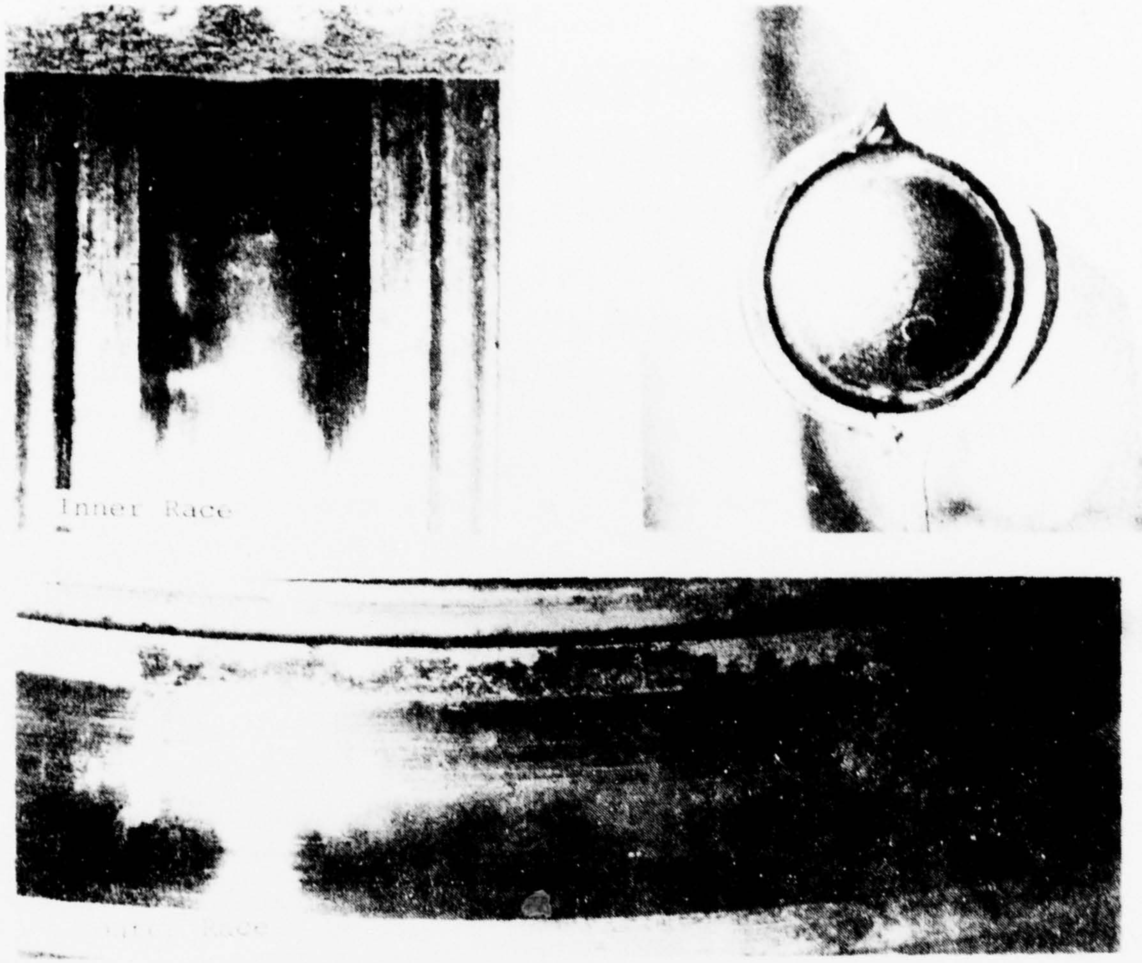

Figure E-59
Implant BHC-060
Hanger Bearing P/N 204-040-623
Not Categorized

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X				6/76	0.2	Part Validation
	X				6/76	4.6	Data Collection
						4.8	Total Time

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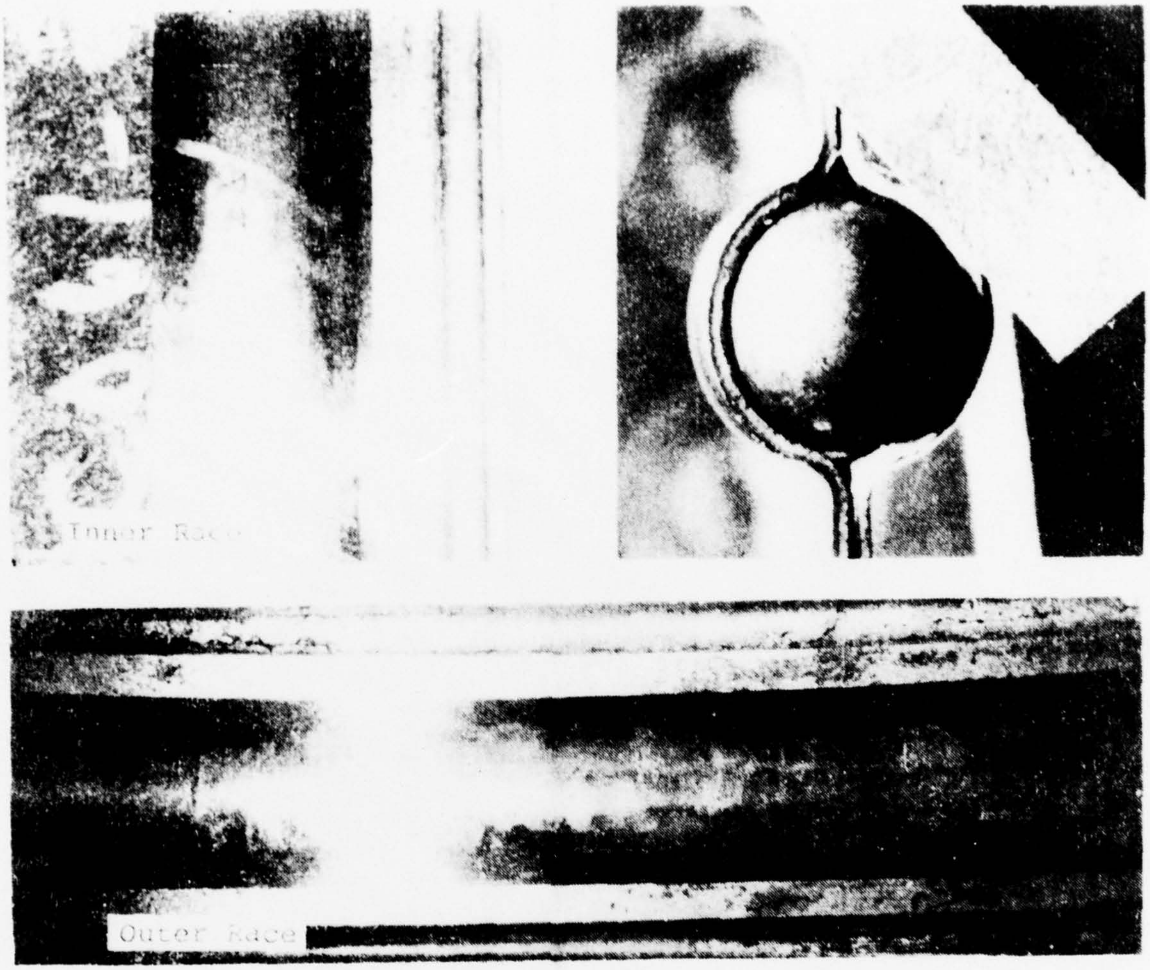

Figure E-60
Implant BHC-061
Hanger Bearing P/N 204-040-623
Not Categorized

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
	X				7/76	0.3	Part Validation
	X				7/76	6.5	Data Collection
						6.8	Total Time

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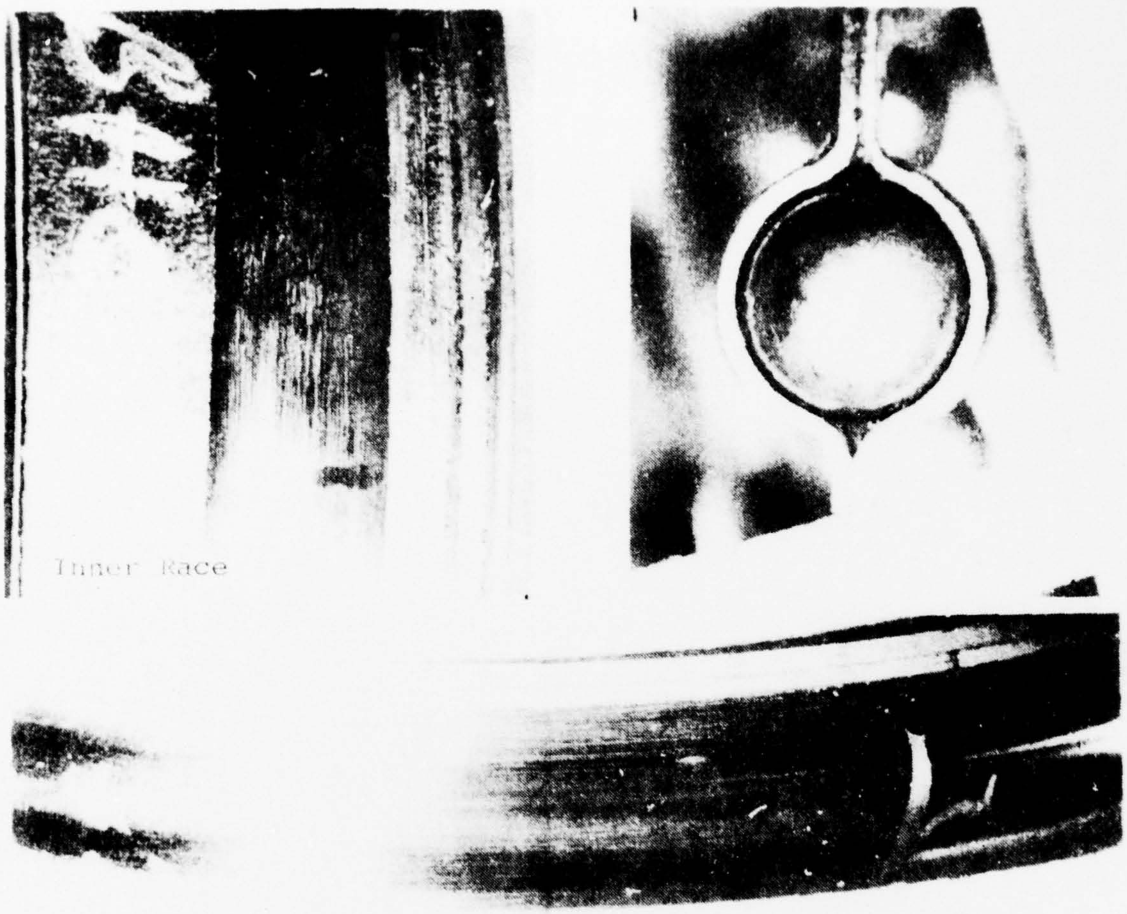

Outer Race

Figure E-61
Implant BHC-063
Hanger Bearing P/N 204-040-623
Not Categorized

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X				7/76	0.1	Part Validation
	X				7/76	5.5	Data Collection
	X				10/76	5.3	Prototype Testing
						10.9	Total Time

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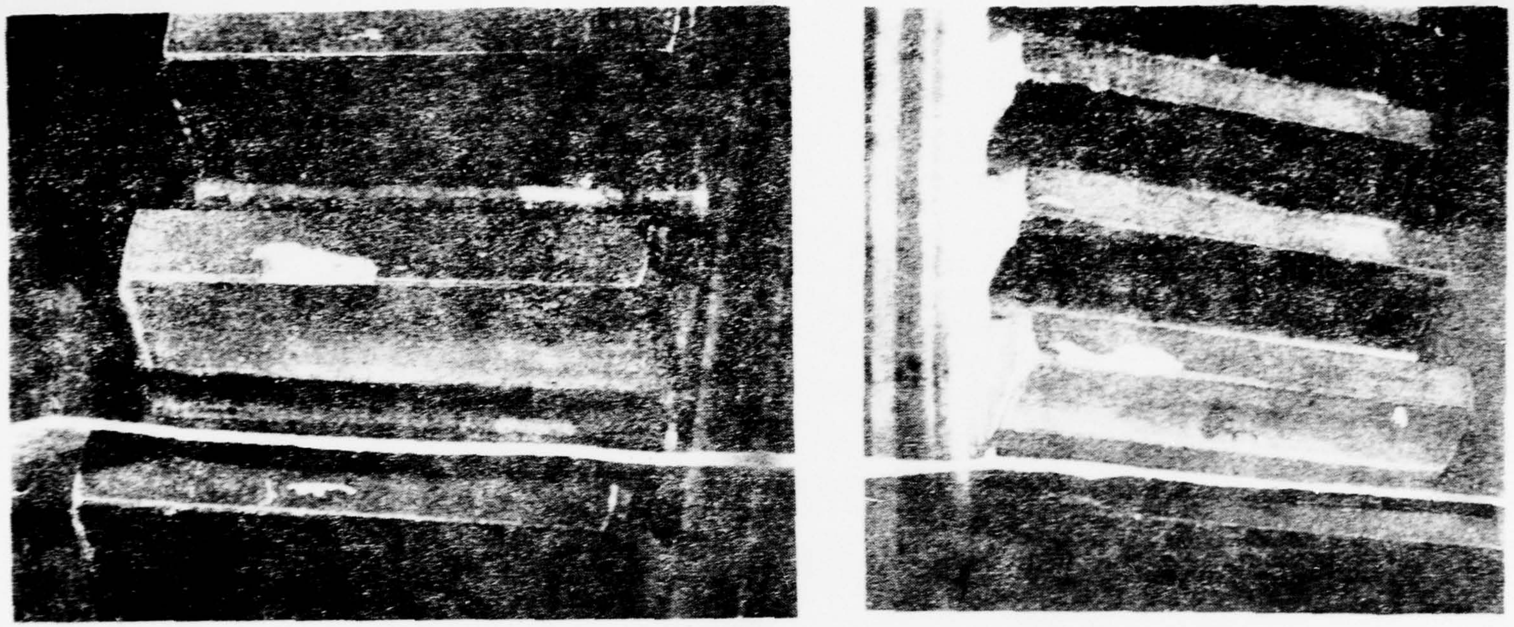

Figure E-62
Implant BHC-067
Transmission Ring Gear P/N 204-040-331, S/N A12-8056
Natural Category "C" Gear Chip (One Upper, One Lower)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
						1.8	Total Time

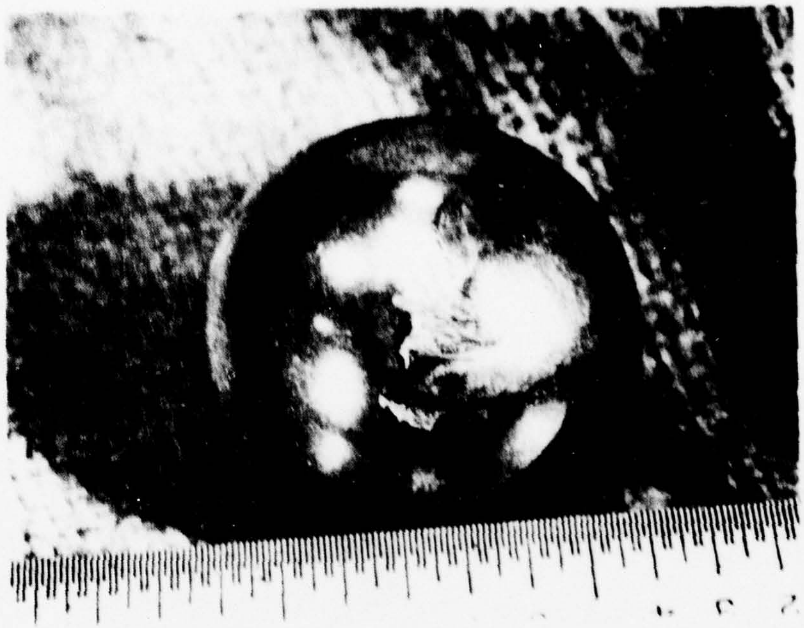

Figure E-63
Implant BHC-068
Ball Bearing P/N 205-040-246, S/N 1771
Natural Category "C" Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
X		X			1/76	91.8	Removal Limit Confidence Test
						93.6	Total Time

Figure E-64
Implant BHC-069
Transmission Tail Rotor Output Gear P/N 204-040-104, S/N B12-6208
Natural Category "D" Score and Spall (Each Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			10/74	1.8	Part Validation
						1.8	Total Time

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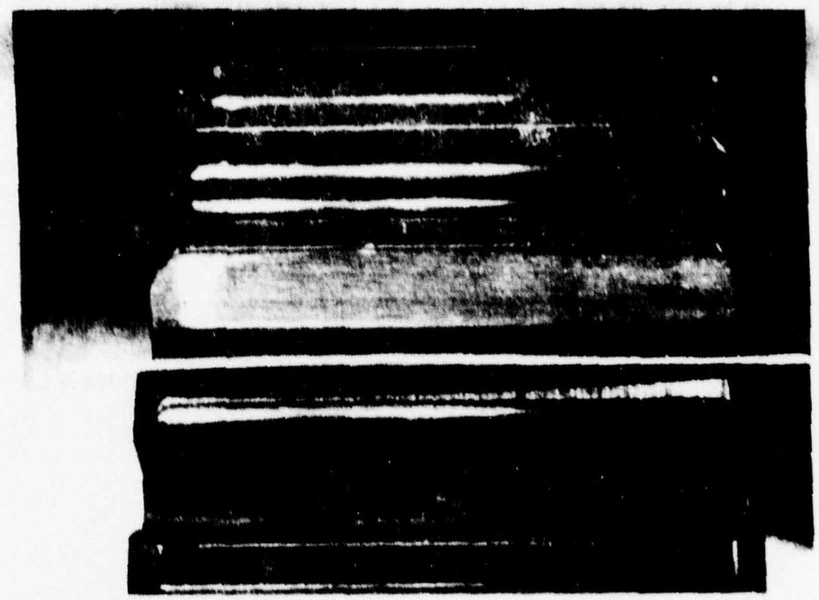

Figure E-65
Implant BHC-070
Transmission Planet Gear P/N 204-040-108, S/N B12-17484
Natural Category "B" Pitting (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
						1.8	Total Time

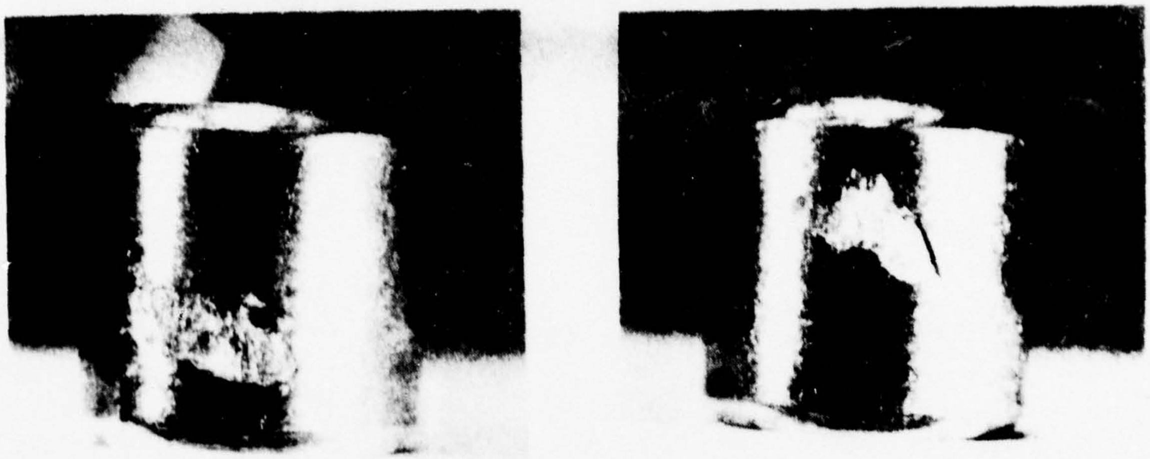

Figure E-66
Implant BHC-071
Transmission Planet Gear Roller Bearing P/N 204-040-725
Natural Category "C" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
X		X			2/76	90.1	Removal Limit Confidence Test Failed
						91.9	Total Time

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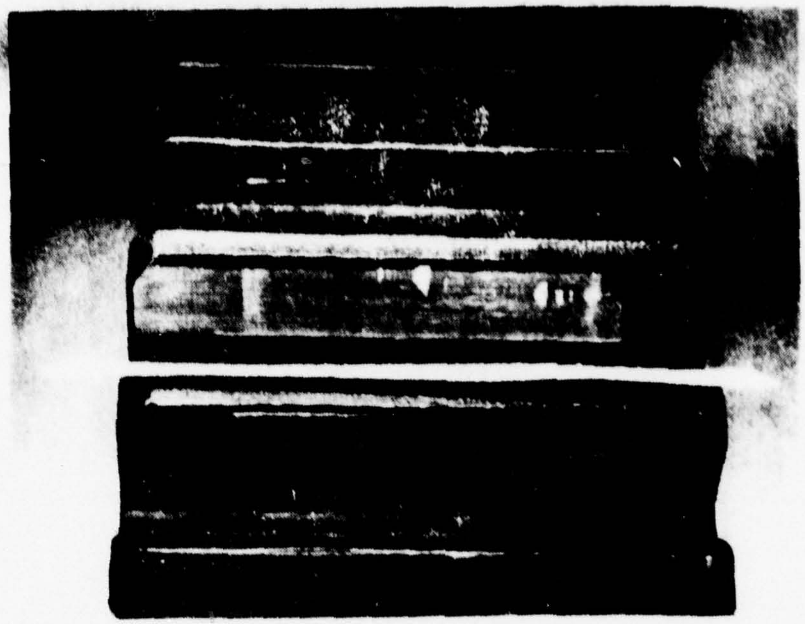

Figure E-67
Implant BHC-072
Transmission Planet Gear P/N 204-040-108 S/N A12-76479
Natural Category "B" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
						1.8	Total Time

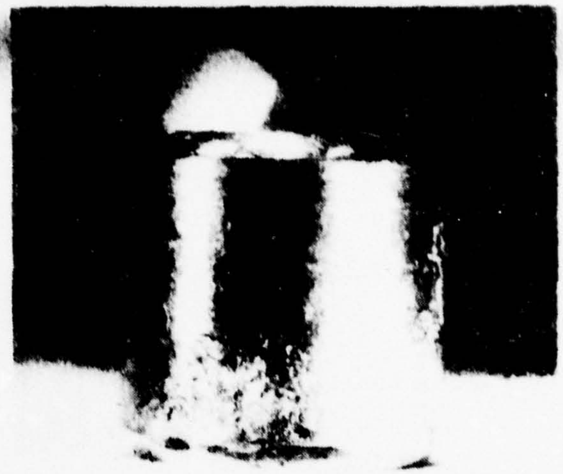

Figure E-68
Implant BHC-073
Transmission Planet Gear Roller Bearing P/N 204-040-725
Natural Category "D" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
X		X			1/76	91.8	Removal Limit Confidence Test Failed
						93.6	Total Time

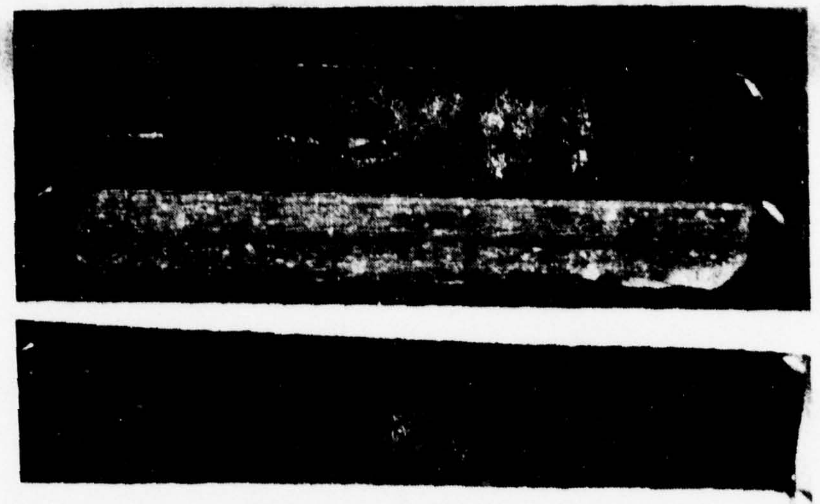

Figure E-69
Implant BHC-074
Transmission Sun Gear P/N 204-040-229, S/N B12-1184
Natural Category "B" Pitting and Spall (Every Tooth)

Installation History

BHT Test Cell	BHT Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
						1.8	Total Time

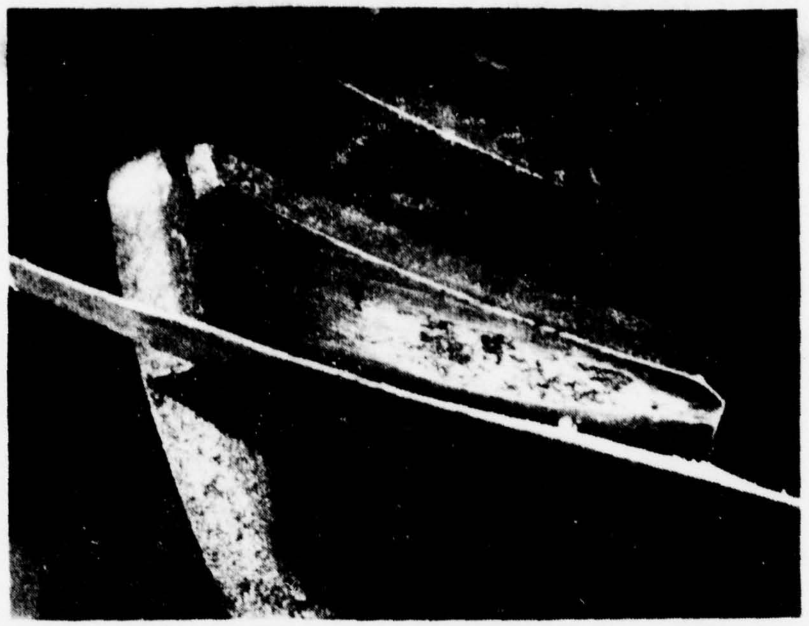

Figure E-70
Implant BHC-075
Transmission Sump Gear P/N 204-040-103, S/N A12-8587
Natural Category "D" Score and Spall (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.8	Part Validation
						1.8	Total Time

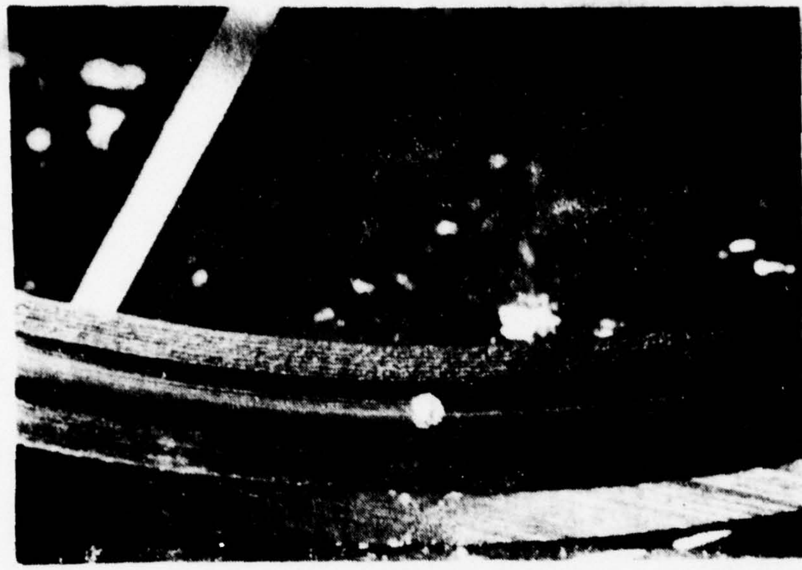

Figure E-71
Implant BHC-076
Ball Bearing P/N 204-040-135, S/N 1002
Artificial Category "C" Outer Race Spall

Installation History

BHT Test Cell	BHT Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
						1.7	Total Time

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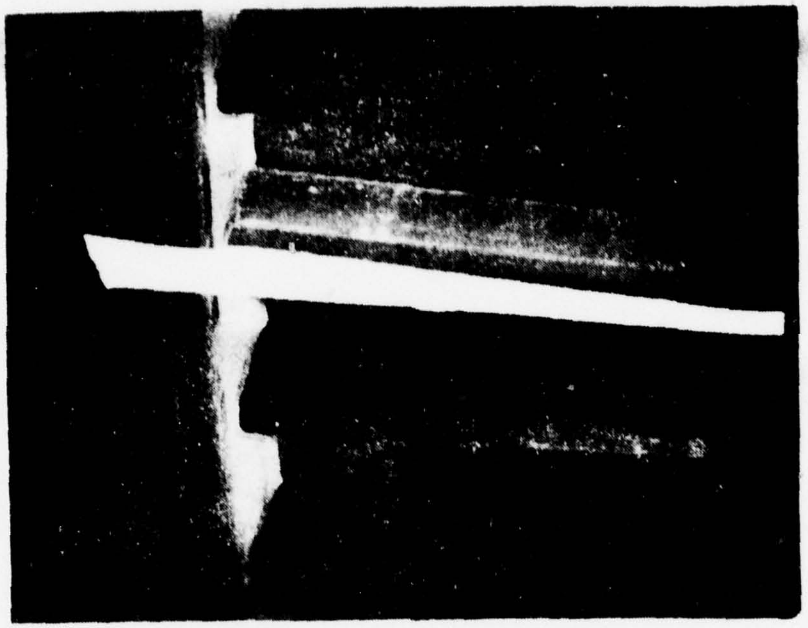

Figure E-72
Implant BHC-077
Transmission Ring Gear P/N 204-040-331, S/N A12-10260
Category "B" Debris Damage (Every Tooth)

Installation History

BHT Test Cell	BHT Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
						1.7	Total Time

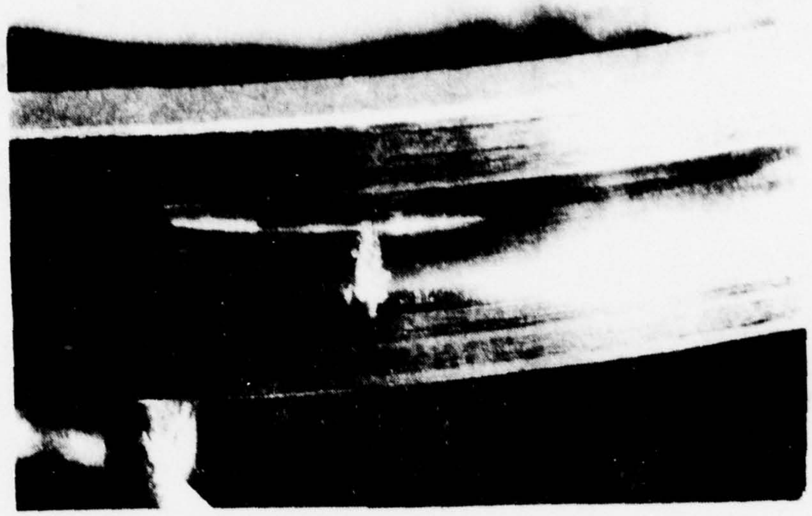

Figure E-73
Implant BHC-078
Ball Bearing P/N 204-040-135, S/N 1001
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	BHT Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
						1.7	Total Time

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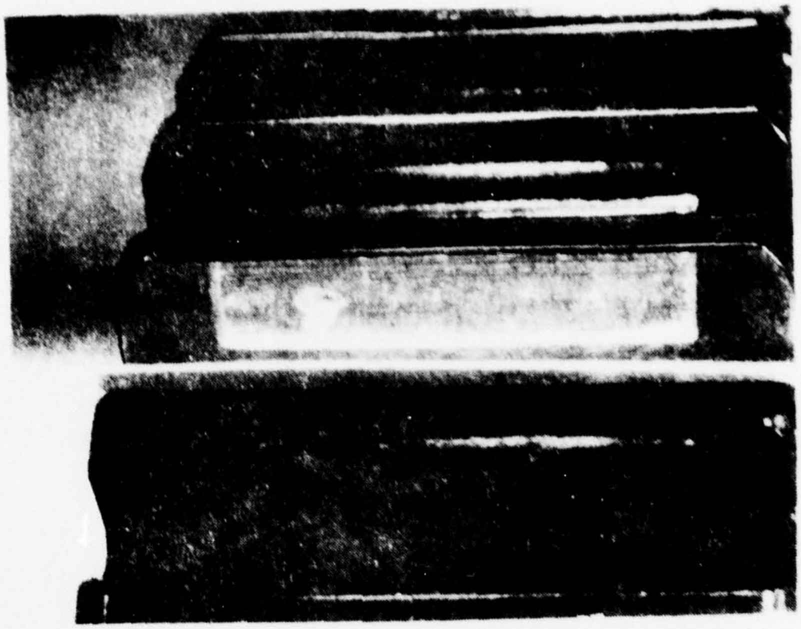

Figure E-74
Implant BHC-079
Transmission Planet Gear P/N 204-040-108, S/N A12-57251
Natural Category "C" Score (Every Tooth) and Spall (One Tooth)

Installation History

BHT Test Cell	BHT Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
	X	X			4/75	4.6	Data Collection
X		X			1/76	91.8	Removal Limit Confidence Test
						98.1	Total Time

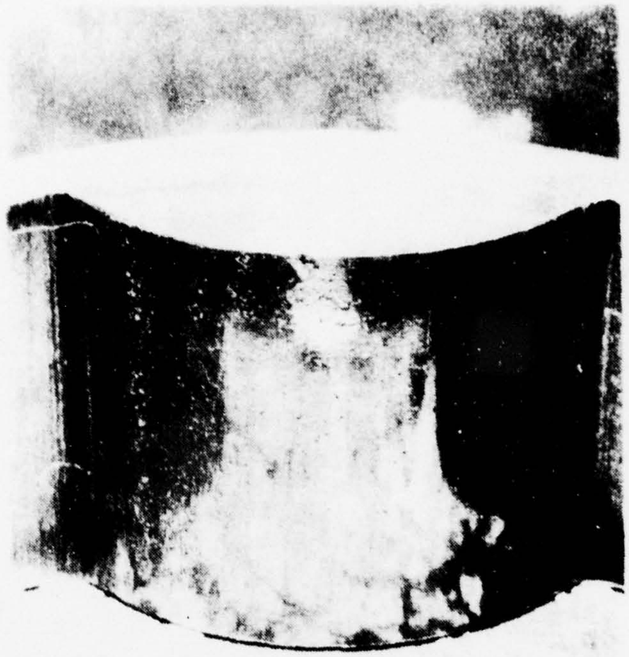

Figure E-75
Implant BHC-080
Transmission Oil Pump P/N GC1669 S/N B-135
Natural Category "C" Pitting

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
						1.7	Total Time

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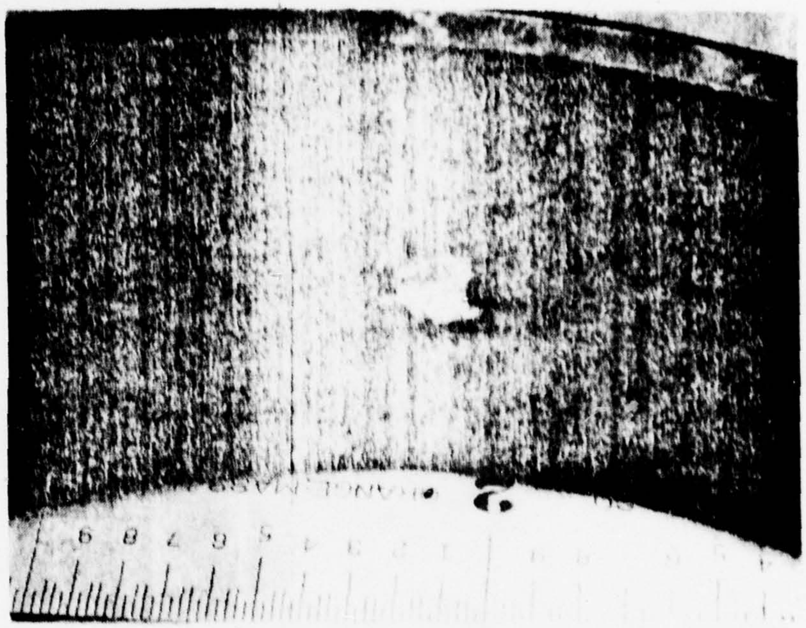

Figure E-76
Implant BHC-081
Ball Bearing P/N 205-040-246, S/N 6879
Artificial Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
	X	X			1/75	4.7	Data Collection
	X	X			2/75	7.3	Data Collection
	X	X			2/75	2.3	Data Collection
	X	X			3/75	4.6	Data Collection
	X	X			4/75	0.8	Data Collection
	X	X			4/75	3.8	Data Collection
	X	X			5/76	7.3	Data Collection
	X	X			6/76	1.0	Data Collection
	X	X			10/76	5.9	Prototype Testing
						39.4	Total Time

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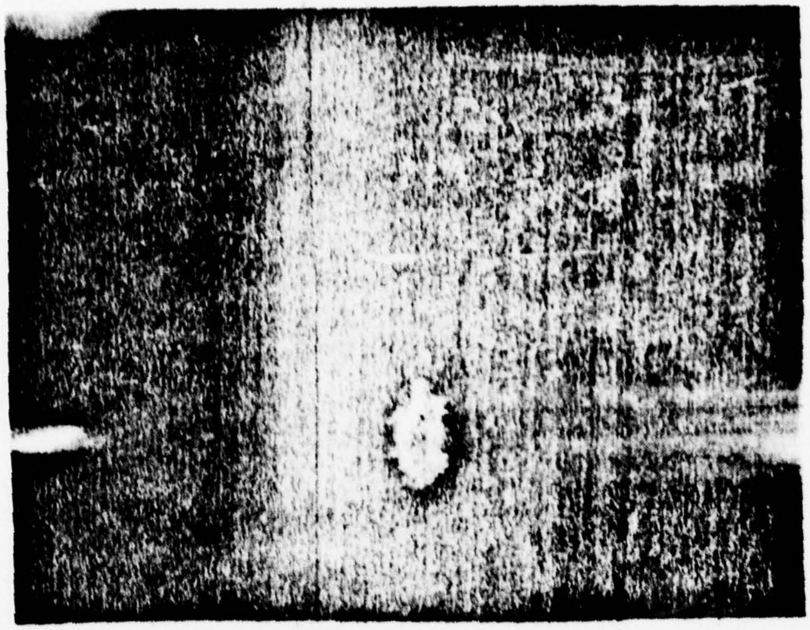

Figure E-77
Implant BHC-082
Ball Bearing P/N 205-040-245, S/N 6924
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
	X	X			1/75	3.3	Data Collection
	X	X			3/75	4.6	Data Collection
	X	X			5/75	4.5	Data Collection
	X	X			9/76	4.6	Prototype Testing
						18.7	Total Time

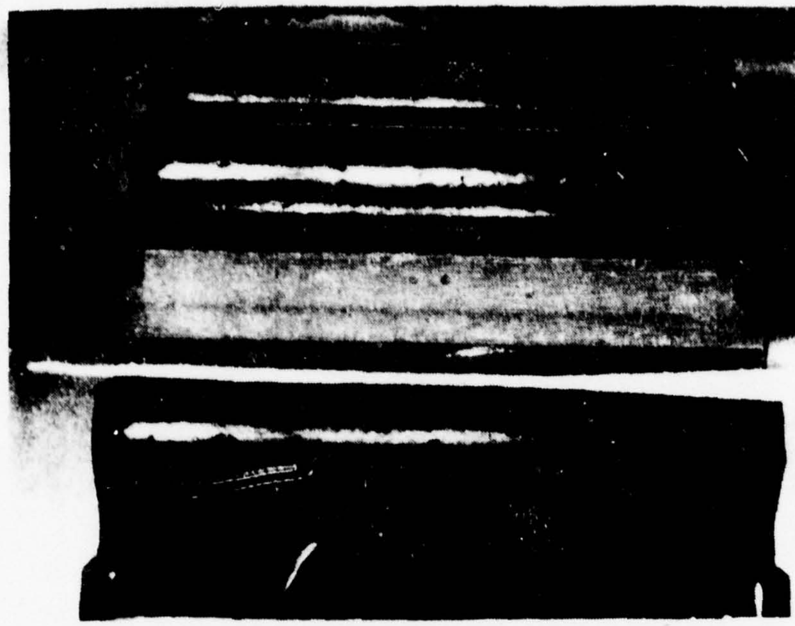

Figure E-78
Implant BHC-083
Transmission Planet Gear P/N 204-040-108, S/N B12-17996
Category "C" Debris Damage (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X					10/74	1.7	Part Validation
X					2/76	90.1	Removal Limit Confidence Test
						91.8	Total Time

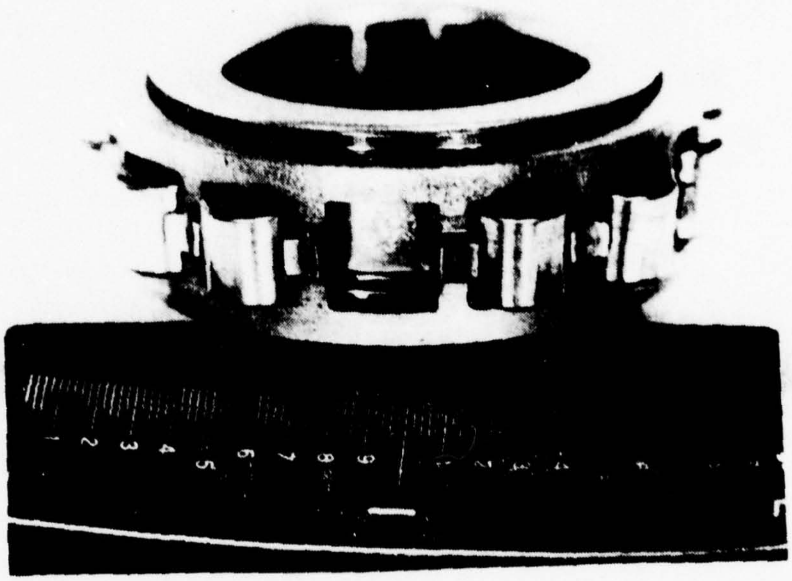

Figure E-79
Implant BHC-084
Roller Bearing P/N 204-040-406, S/N 5H
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X			X	11/74	3.6	Part Validation
						3.6	Total Time

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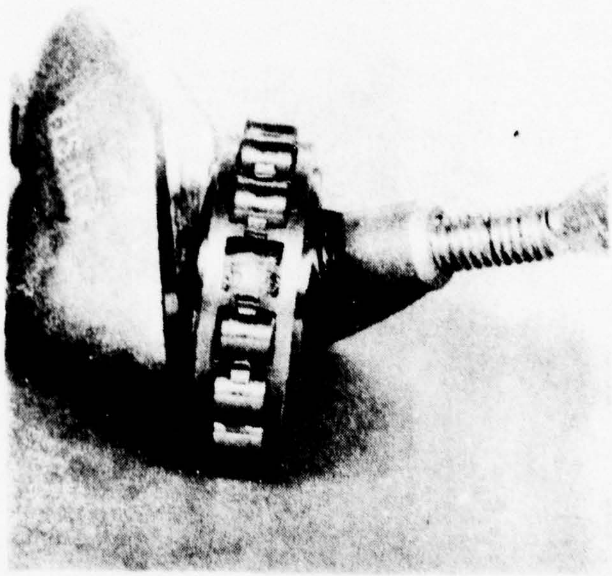

Figure E-80
Implant BHC-085
Roller Bearing P/N 204-040-406, S/N 3322
Artificial Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
	X			X	3/75	0.2	Part Validation
	X			X	3/75	3.5	Data Collection
	X			X	3/75	3.4	Data Collection
	X			X	3/76	8.0	Data Collection
	X			X	9/76	6.0	Prototype Testing
						21.1	Total Time

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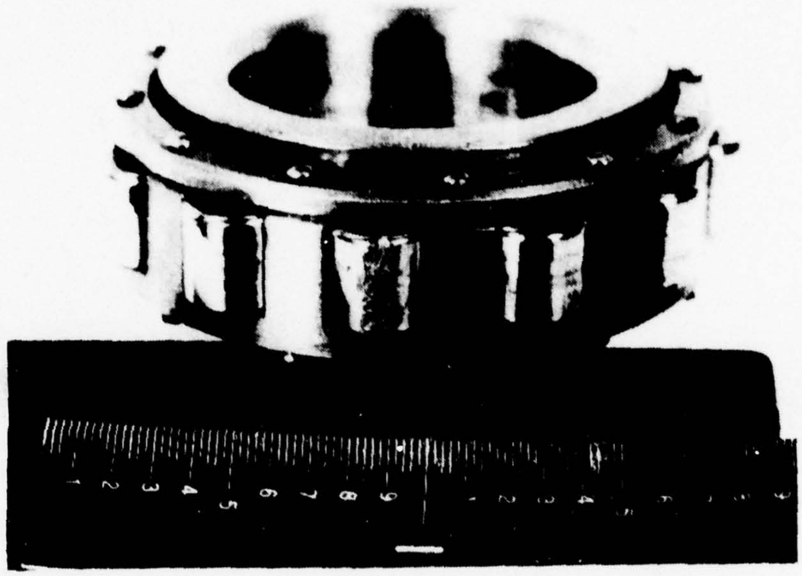

Figure E-81
Implant BHC-086
Roller Bearing P/N 204-040-406 S/N 21093
Artificial Category "D" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X			X	1/75	0.1	Part Validation
	X			X	1/75	3.6	Data Collection
	X			X	7/76	6.1	Data Collection
	X			X	7/76	1.7	Data Collection
						11.5	Total Time

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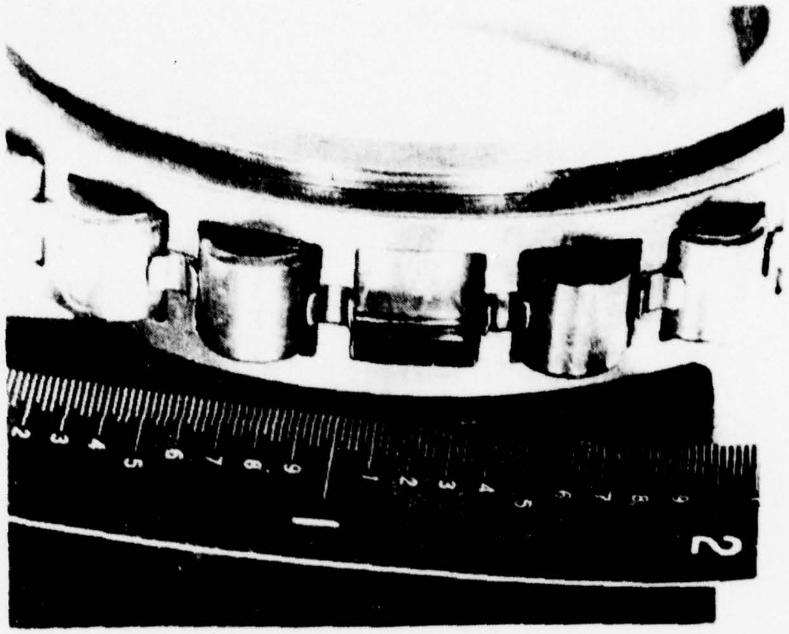

Figure E-82
Implant BHC-087
Roller Bearing P/N 204-040-407 S/N 16292
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			10/74	1.7	Part Validation
	X	X			1/75	3.3	Data Collection
	X	X			3/75	4.6	Data Collection
	X	X			5/75	4.5	Data Collection
						14.1	Total Time

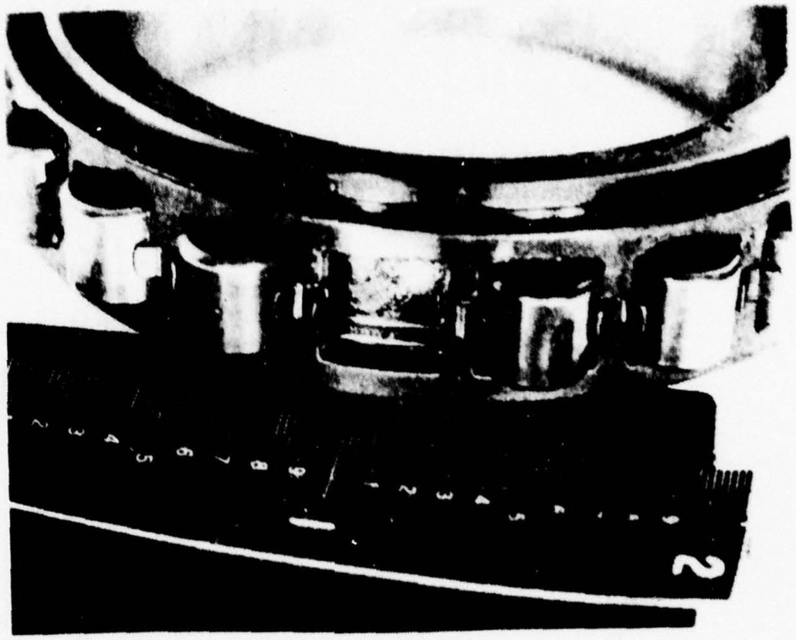

Figure E-83
Implant BHC-088
Roller Bearing P/N 204-040-407, S/N 23222
Artificial Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X			X	2/75	0.4	Part Validation
	X			X	2/75	3.2	Data Collection
	X			X	10/76	6.3	Prototype Testing
						9.9	Total Time

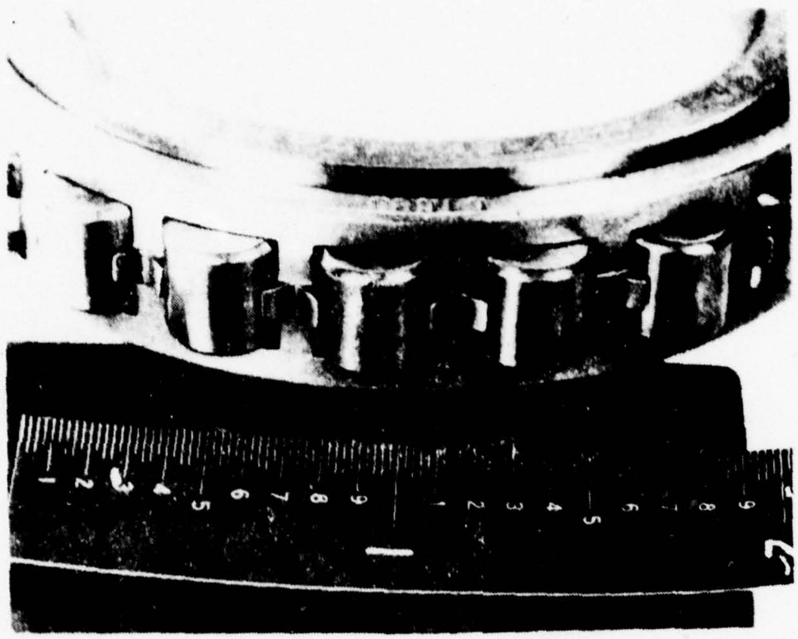

Figure E-84
Implant BHC-089
Roller Bearing P/N 204-040-407, S/N 29119
Artificial Category "D" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X			X	1/75	0.3	Part Validation
	X			X	1/75	4.2	Data Collection
	X			X	3/76	7.2	Data Collection
	X			X	8/76	6.5	Data Collection
	X			X	8/76	1.2	Data Collection
						19.4	Total Time

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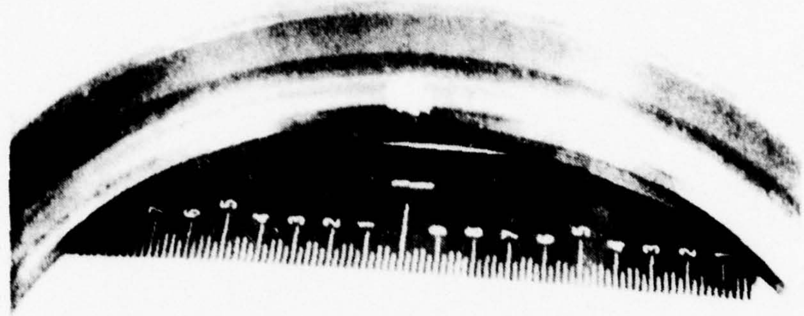

Figure E-85
Implant BHC-090
Ball Bearing P/N 204-040-424, S/N 19130
Artificial Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
	X			X	11/74	3.6	Part Verification
	X			X	1/75	4.7	Data Collection
	X			X	2/75	7.3	Data Collection
	X			X	2/75	2.3	Data Collection
	X			X	2/75	4.5	Data Collection
	X			X	3/75	0.4	Data Collection
	X			X	3/75	4.5	Data Collection
	X			X	5/75	3.8	Data Collection
	X			X	5/76	5.5	Data Collection
	X			X	6/76	0.9	Data Collection
	X			X	10/76	5.9	Prototype Testing
						43.4	Total Time

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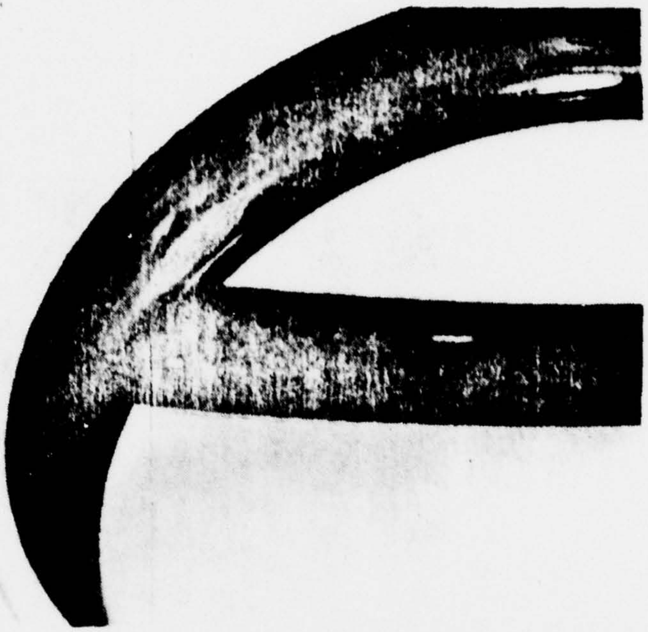

Figure E-86
Implant BHC-091
Ball Bearing P/N 204-040-424, S/N 29824
Artificial Category "D" Outer Race Spall

Installation History

BHC Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X			X	12/74	0.9	Part Validation
	X			X	12/74	2.6	Data Collection
	X			X	12/74	4.2	Data Collection
	X			X	4/75	3.5	Data Collection
	X			X	10/76	4.3	Prototype Testing
						15.5	Total Time

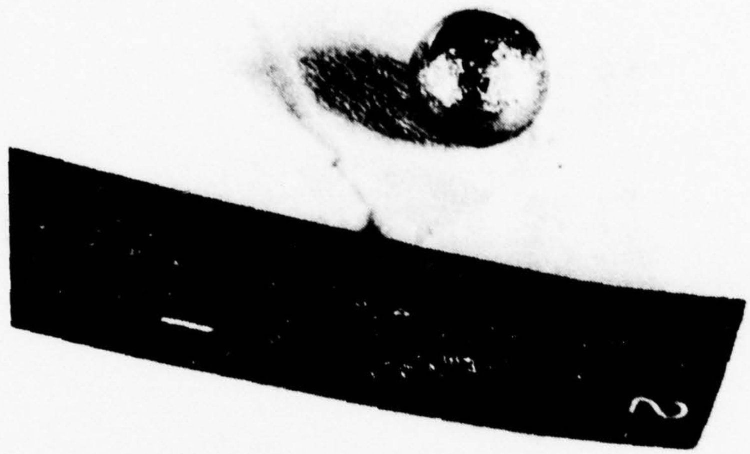

Figure E-87
Implant BHC-092
Ball Bearing P/N 204-040-424, S/N H792
Artificial Category "D" Ball Spall

Installation History

No Test Runs.

Figure E-88
Implant BHC-093
Ball Bearing P/N 205-040-246, S/N 460
Artificial Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			11/74	0.1	Part Validation
	X	X			11/74	3.5	Data Collection
	X	X			1/75	3.7	Data Collection
	X	X			2/75	4.9	Data Collection
	X	X			2/75	3.9	Data Collection
	X	X			2/76	6.2	Data Collection
	X	X			10/76	4.3	Prototype Testing
						26.6	Total Time

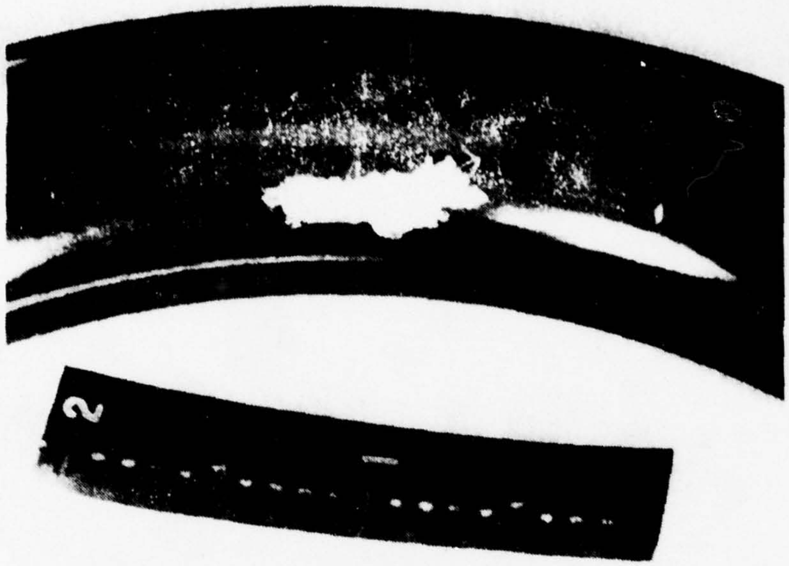

Figure E-89
Implant BHC-094
Ball Bearing P/N 205-040-246, S/N 7675
Artificial Category "D" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			12/74	0.1	Part Validation
	X	X			12/74	4.1	Data Collection
	X	X			3/75	3.0	Data Collection
	X	X			5/75	3.4	Data Collection
	X	X			6/75	5.5	Data Collection
	X	X			4/76	4.5	Data Collection
						20.6	Total Time

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Figure E-90
Implant BHC-095
Ball Bearing P/N 205-040-245 S/N 1986
Artificial Category "D" Inner Race Spall

Installation History

No Test Runs

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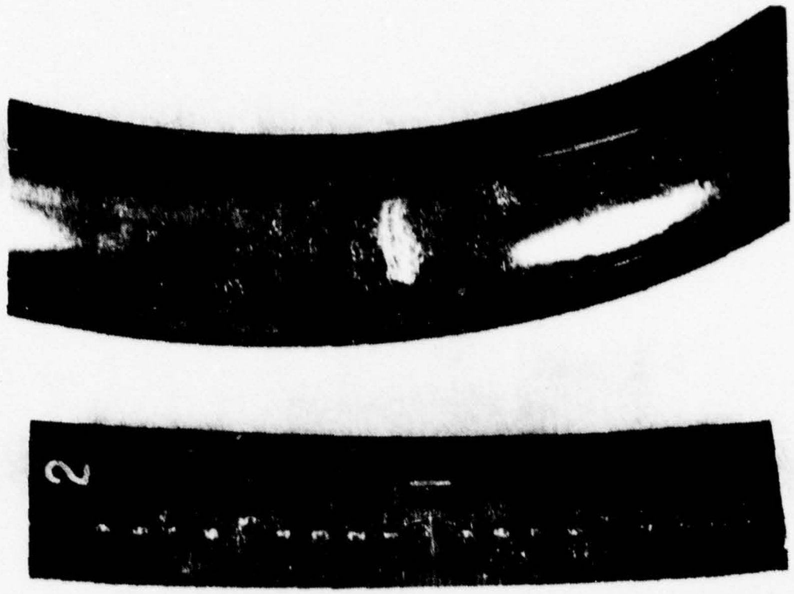

Figure E-91
Implant BHC-096
Ball Bearing P/N 204-040-136 S/N 457
Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			10/74	0.1	Part Validation
	X	X			10/74	1.3	Data Collection
	X	X			4/75	4.5	Data Collection
	X	X			6/75	3.2	Data Collection
	X	X			6/76	6.7	Data Collection
	X	X			7/76	1.5	Data Collection
	X	X			8/76	4.5	Data Collection
	X	X			8/76	0.9	Data Collection
						22.7	Total Time

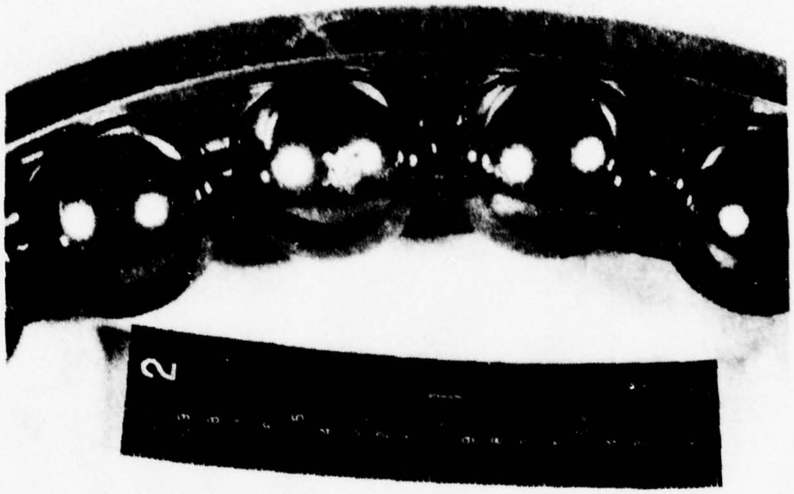

Figure E-92
Implant BHC-097
Ball Bearing P/N 204-040-136, S/N 2729
Artificial Category "C" Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			11/74	2.2	Part Validation
	X	X			3/75	4.5	Data Collection
	X	X			1/76	4.8	Data Collection
	X	X			5/76	2.9	Data Collection
						14.4	Total Time

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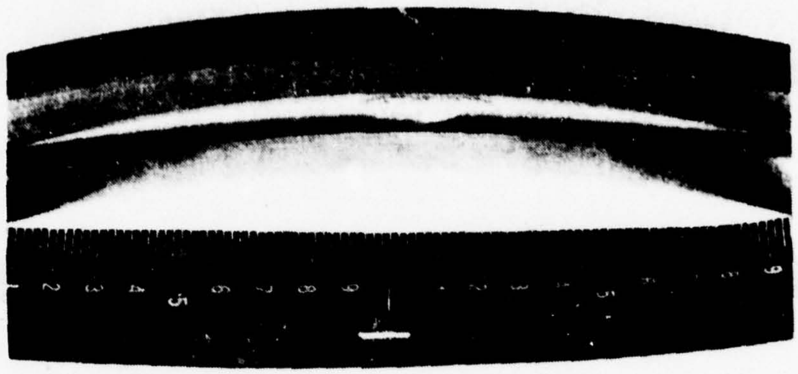

Figure E-93
Implant BHC-098

Ball Bearing P/N 204-040-135, S/N 1003
Artificial Category "D" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			1/75	0.1	Part Validation
	X	X			1/75	3.6	Data Collection
	X	X			2/75	3.6	Data Collection
	X	X			3/75	3.4	Data Collection
	X	X			4/75	3.4	Data Collection
	X	X			5/75	2.9	Data Collection
	X	X			3/76	7.2	Data Collection
	X	X			4/76	9.9	Data Collection
	X	X			5/76	5.5	Data Collection
	X	X			7/76	8.0	Data Collection
	X	X			8/76	7.1	Data Collection
	X	X			9/76	5.3	Data Collection
	X	X			10/76	5.7	Data Collection
	X	X			11/76	6.6	Data Collection
						72.3	Total Time

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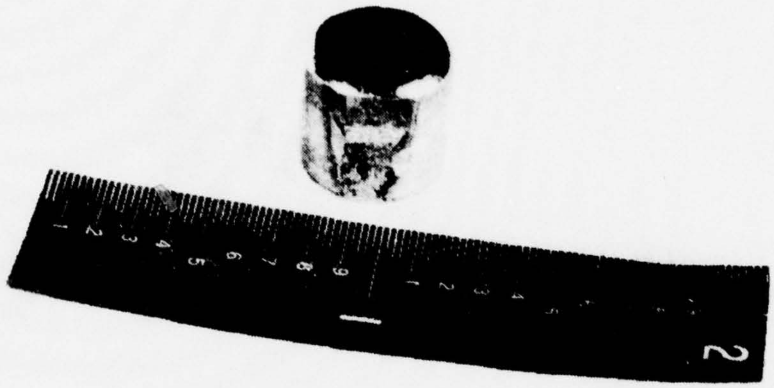

Figure E-94
Implant BHC-099
Roller Bearing P/N 204-040-725
Artificial Category "D" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			3/75	0.9	Part Validation
	X	X				2.6	Data Collection
	X	X			10/76	2.3	Data Collection
						5.8	Total Time

Figure E-95
Implant BHC-101
90-degree Gearbox Pinion P/N 204-040-400, S/N B13-6158
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	3/75	5.4	Part Validation
X				X	3/75	40.5	Degradation Rate Test
X				X	4/75	40.0	Degradation Rate Test
X				X	4/75	40.0	Degradation Rate Test
	X			X	7/75	3.6	Data Collection
	X			X	7/75	3.1	Data Collection
X				X	2/76	90.1	Removal Limit Confidence Test
						233.5	Total Time

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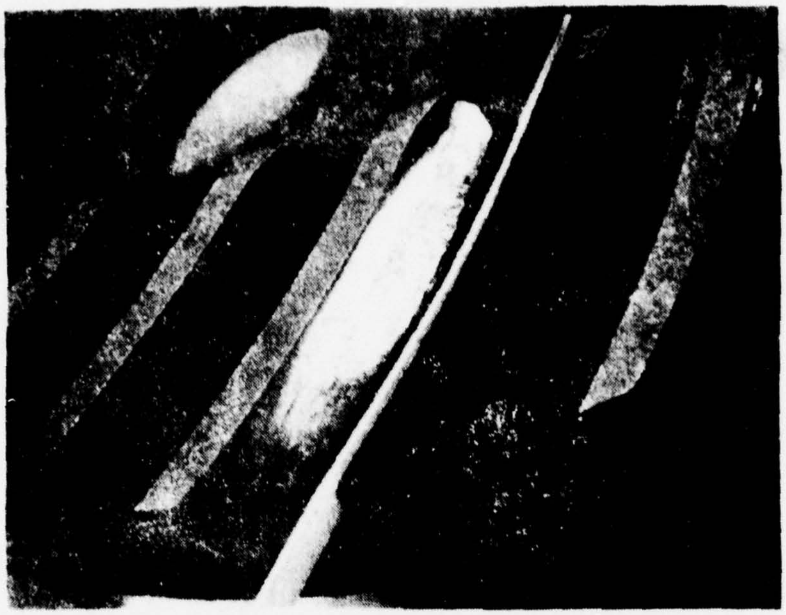

Figure E-96
Implant BHC-102
90-degree Gearbox Gear P/N 204-040-401, S/N A13-12204
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	3/75	5.4	Part Validation
X				X	3/75	40.5	Degradation Rate Test
X				X	4/75	40.0	Degradation Rate Test
X				X	4/75	40.0	Degradation Rate Test
	X			X	7/75	3.6	Data Collection
				X	7/75	3.1	Data Collection
X				X	2/76	90.1	Removal Limit Confidence Test
						233.5	Total Time

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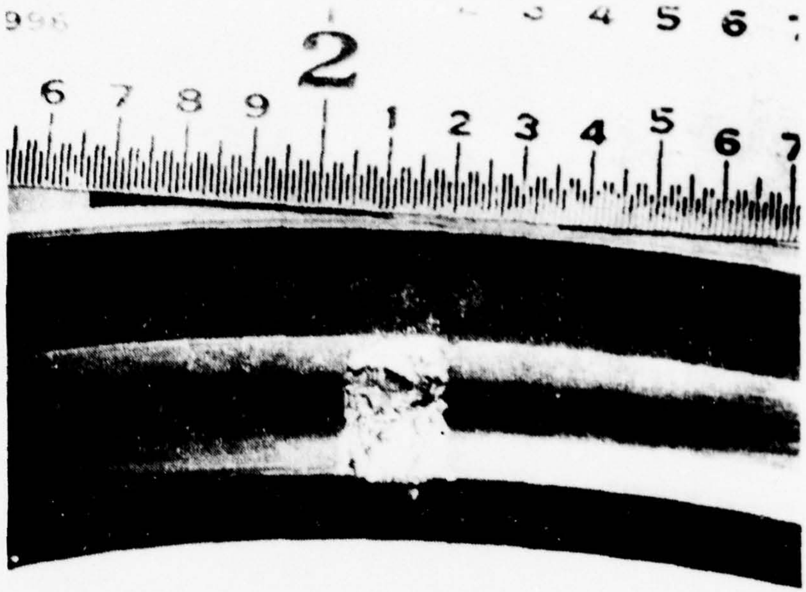

Figure E-97
Implant BHC-103
Ball Bearing P/N 204-040-424, S/N 34654
Artificial Category "D" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X			X	7/75	0.2	Part Validation
	X			X	7/75	3.6	Data Collection
	X			X	9/76	7.5	Data Collection
						11.3	Total Time

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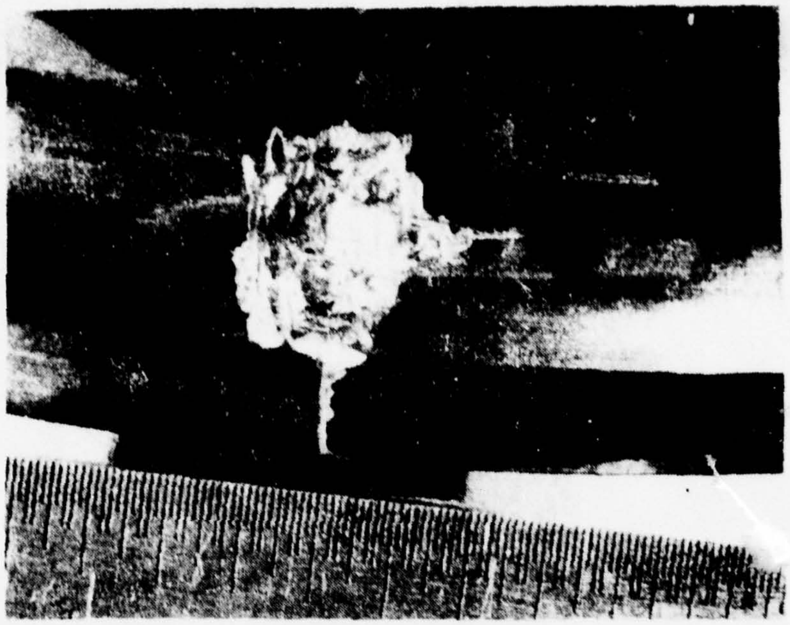

Figure E-98
Implant BHC-104
Ball Bearing P/N 205-040-245, S/N 2542
Artificial Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X	X			3/75	0.2	Part Validation
	X	X			3/75	3.5	Data Collection
	X	X			3/75	3.4	Data Collection
	X	X			4/75	3.4	Data Collection
	X	X			3/76	2.8	Data Collection
						13.3	Total Time

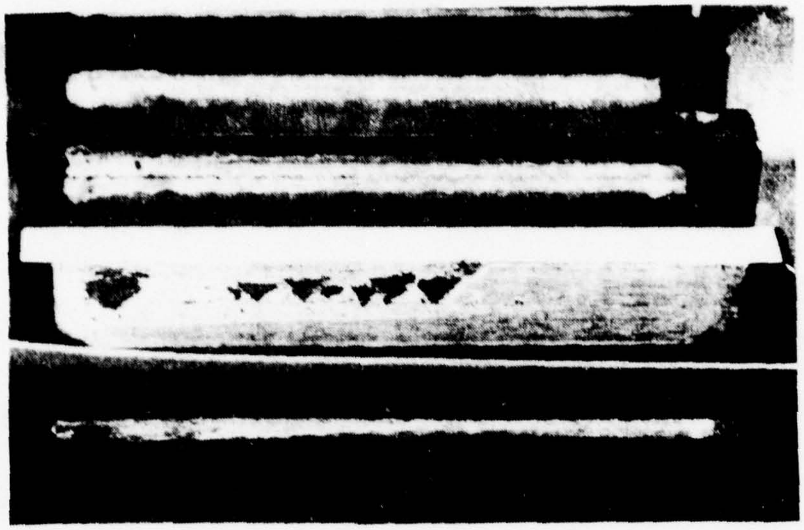

Figure E-99
Implant BHT-105
Transmission Sun Gear P/N 204-040-330, S/N B12-11172
Natural Category "D" Spall (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			3/75	40.5	Degradation Rate Test
X		X				40.0	Degradation Rate Test
X		X				40.0	Degradation Rate Test
	X	X			9/76	1.2	Data Collection
						121.7	Total Time

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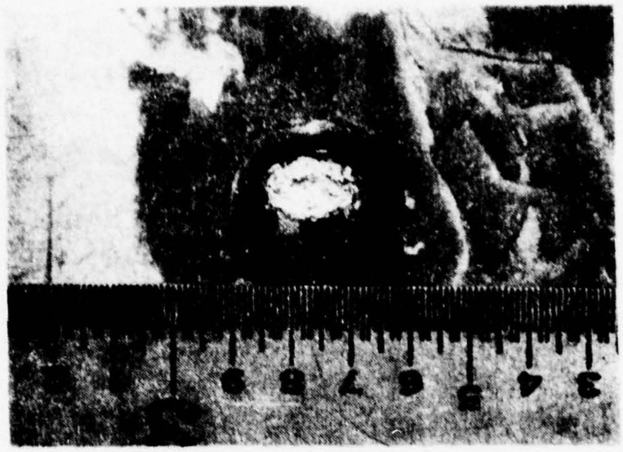

Figure E-100
Implant BHC-106
Ball Bearing P/N 204-040-424, S/N 34526
Artificial Category "D" Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X			X	5/75	0.3	Part Validation
	X			X	5/75	2.6	Data Collection
	X			X	6/75	3.3	Data Collection
	X			X	6/75	2.8	Data Collection
	X			X	3/76	2.8	Data Collection
	X			X	10/76	4.5	Prototype Testing
						16.3	Total Time

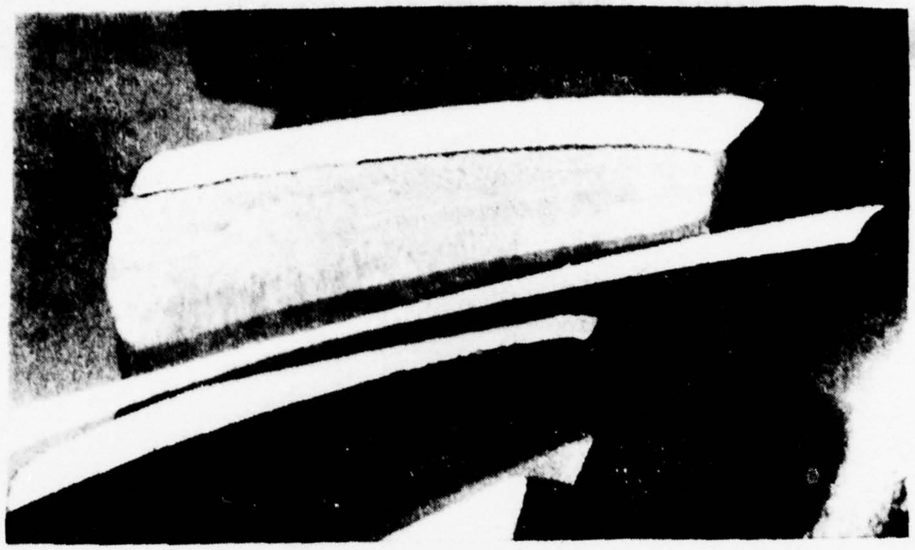

Figure E-101
Implant BHC-109
42-degree Gearbox Pinion P/N 204-040-500-9, S/N 14411-9
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
	X		X		7/75	3.9	Part Validation
	X		X		7/75	3.2	Data Collection
X			X		1/76	43.8	Removal Limit Confidence Test Failed
						50.9	Total Time

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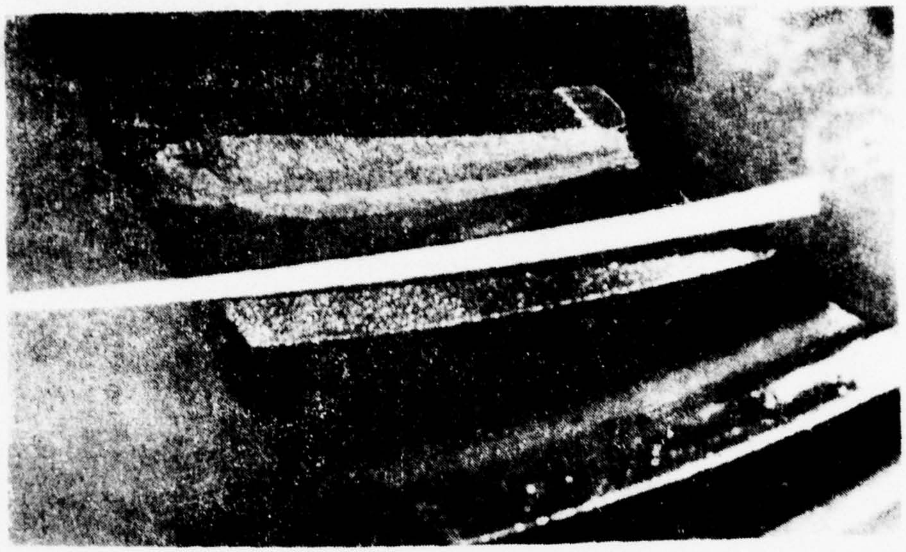

Figure E-102
Implant BHC-110
42-degree Gearbox Gear P/N 204-040-500-10, S/N 30245
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X		X		7/75	3.9	Part Validation
	X		X		7/75	3.2	Data Collection
X		X			1/76	43.8	Removal Limit Confidence Test Failed
						50.9	Total Time

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Figure E-103
Implant BHC-111
42-degree Gearbox Pinion P/N 204-040-500-9, S/N 10194
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X		X		7/75	5.0	Part Validation/ Data Collection
	X		X			3.3	Data Collection
X			X			90.1	Removal Limit Confidence Test
	X		X		4/76	4.0	Prototype Test
	X		X		9/76	5.9	Prototype Test
	X		X		10/76	4.5	Prototype Test
						112.8	Total Time

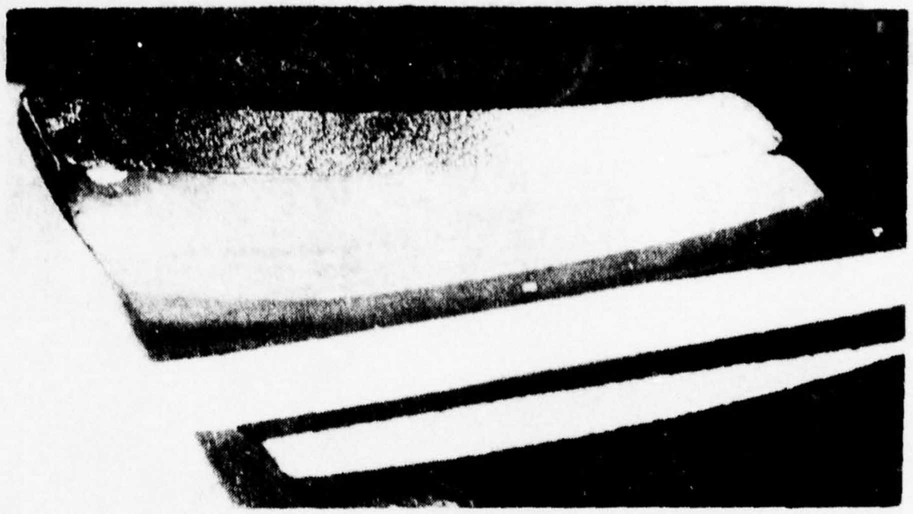

Figure E-104
Implant BHC-112
42-degree Gearbox Pinion P/N 204-040-500-10, S/N 10694
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X		X		7/75	5.0	Part Validation
	X		X		7/75	3.3	Data Collection
X			X		2/76	90.1	Removal Limit Confidence Test
	X		X		4/76	4.0	Prototype Testing
	X		X		10/76	4.5	Prototype Testing
						106.9	Total Time

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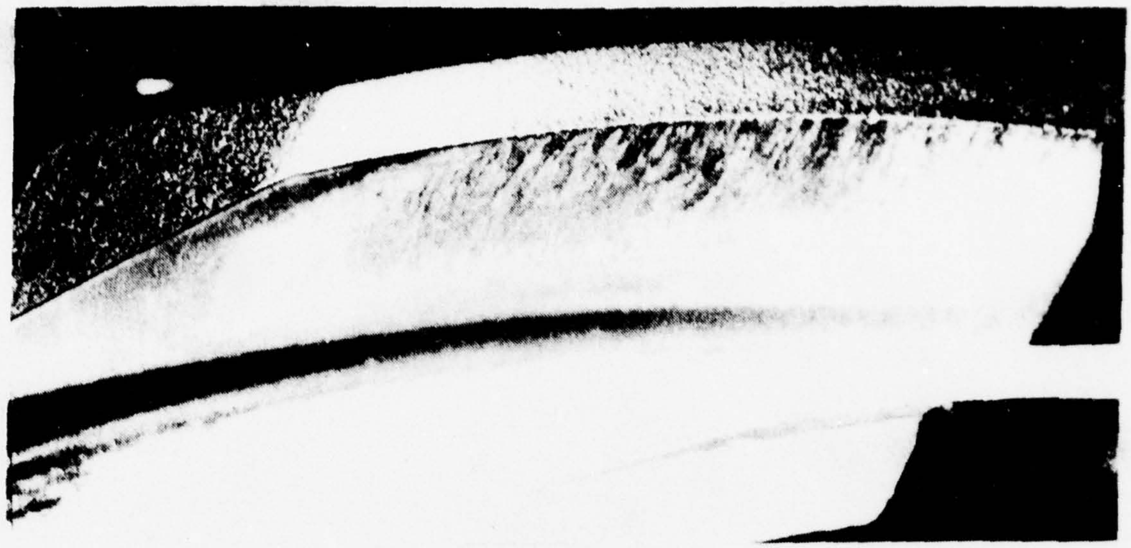

Figure E-105
Implant BHC-113
90-degree Gearbox Pinion P/N 204-040-400, S/N B13-15309
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
	X			X	7/75	2.4	Part Validation
	X			X	7/75	5.0	Data Collection
X				X	1/76	62.1	Removal Limit Confidence Test
	X			X	6/76	3.8	Prototype Testing
						103.0	Total Time

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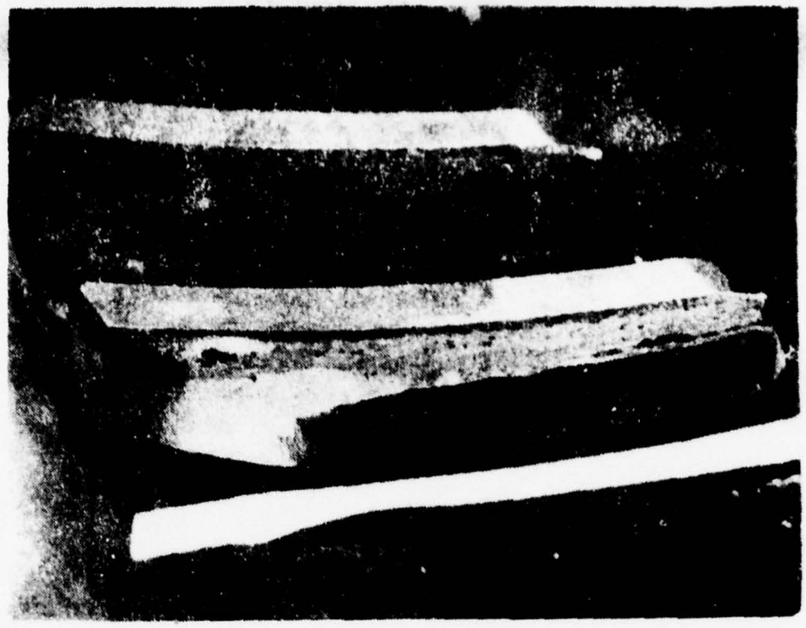

Figure E-106
Implant BHC-114
90-degree Gearbox P/N 204-040-401, S/N A13-14986
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
	X			X	7/75	2.4	Part Validation
	X			X	7/75	5.0	Data Collection
X				X	1/76	62.1	Removal Limit
X				X	1/76	29.7	Confidence Test
	X			X	6/76	3.8	Prototype Testing
						103.0	Total Time

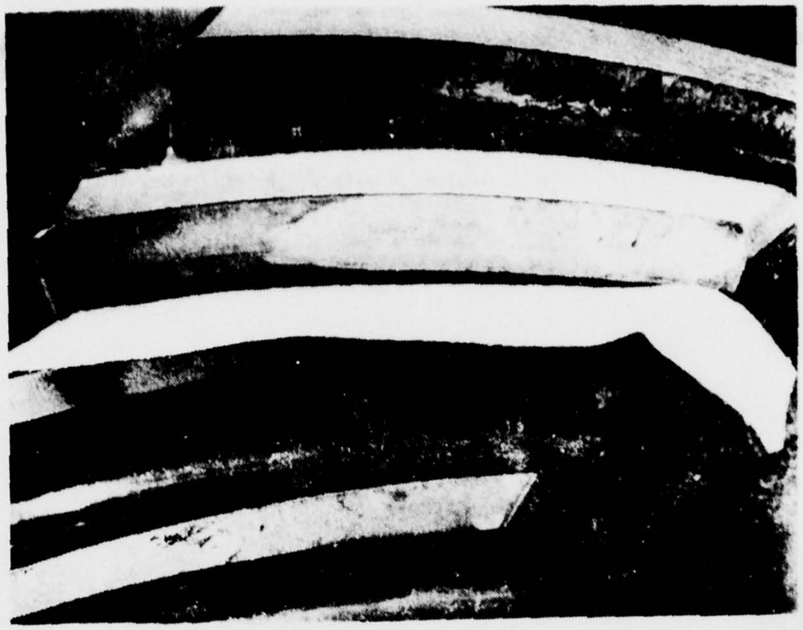

Figure E-107
Implant BHC-115
Transmission Input Pinion P/N 204-040-700, S/N B12-7211
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit Confidence Test
	X	X			8/76	5.8	Prototype Testing
	X	X			8/76	0.7	Prototype Testing
						91.8	Total Time

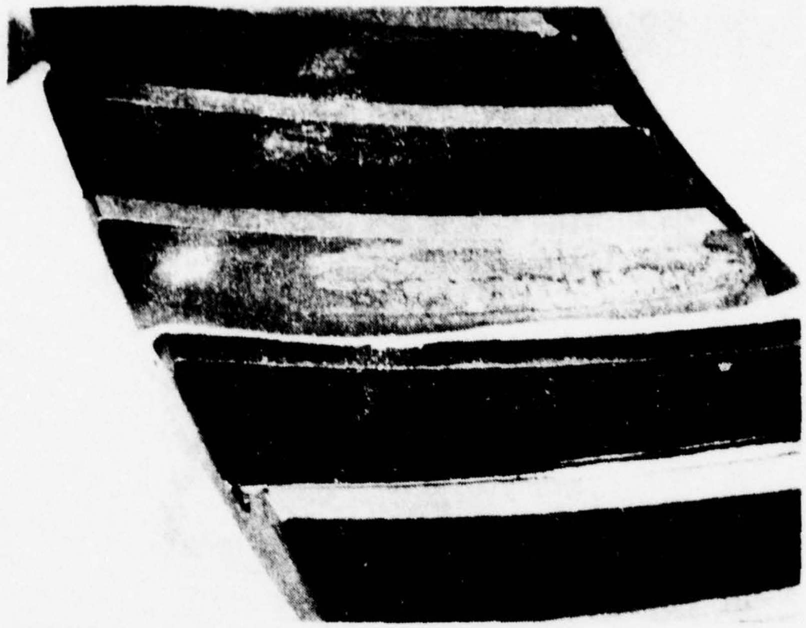

Figure E-108
Implant BHC-116
Transmission Input Gear P/N 204-040-701, S/N B12-7793
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit Confidence Test
	X	X			8/76	5.8	Data Collection
	X	X			8/76	0.7	Data Collection
						98.3	Total Time

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(Photograph not available)

Figure E-109
Implant BHC-122
Hanger Bearing P/N 204-040-623
(Not Categorized)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
	X				7/75	0.8	Part Validation
	X				8/76	4.5	Data Collection
						5.3	Total Time

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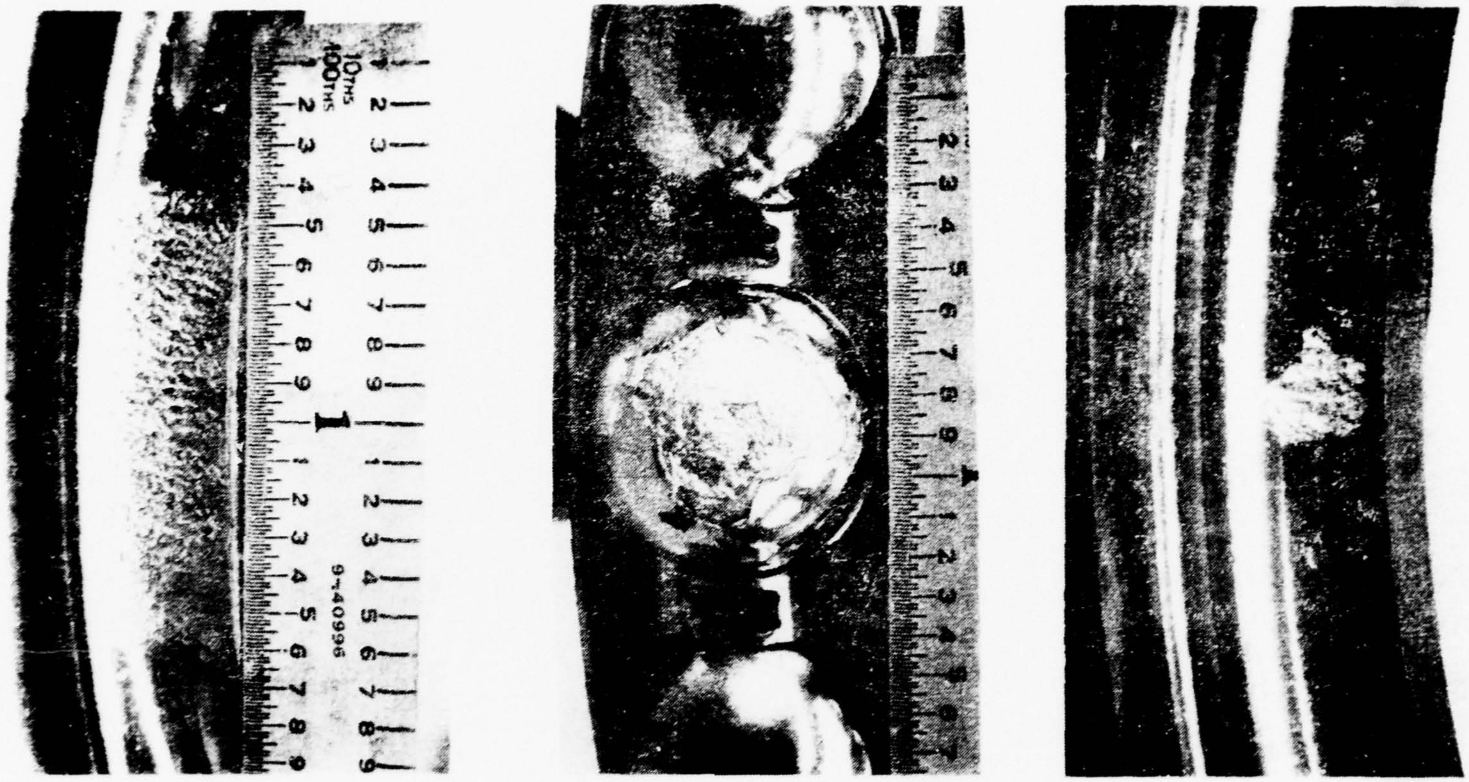

Figure E-110
Implant BHC-123
Ball Bearing P/N 204-040-136, S/N A1205
Natural Category "D" Inner Race, Outer Race and Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit Confidence Test
						91.8	Total Time

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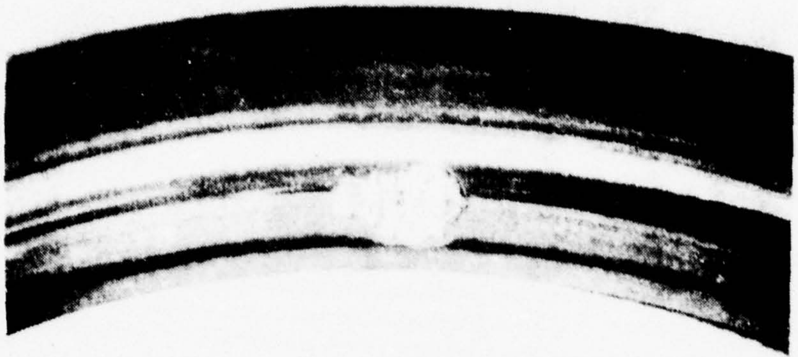

Figure E-111
Implant BHC-124
Ball Bearing P/N 204-040-136, S/N 9727
Natural Category "D" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			2/76	90.1	Removal Limit Confidence Test
	X	X			2/76	4.9	Prototype Test
	X	X			8/76	1.0	Prototype Test
	X	X			9/76	5.2	Prototype Test
						101.2	Total Time

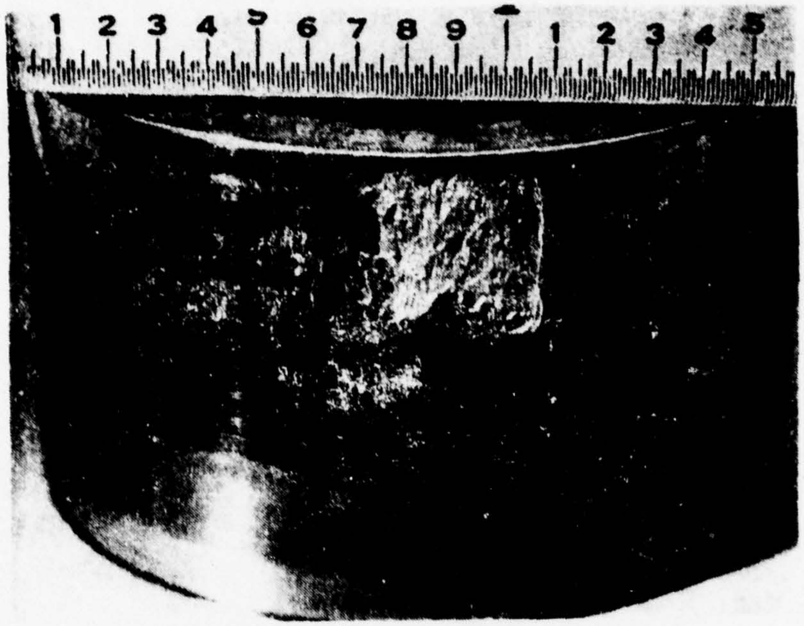

Figure E-112
Implant BHC-126
Planet Bearing Inner Race P/N 204-040-132
Natural Category "D" Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit Confidence Test
						91.8	Total Time

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Figure E-113
Implant BHC-127
42-degree Gearbox Pinion P/N 204-040-500-9, S/N A13-21083
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		1/76	48.0	Removal Limit Confidence Test
						48.0	Total Time

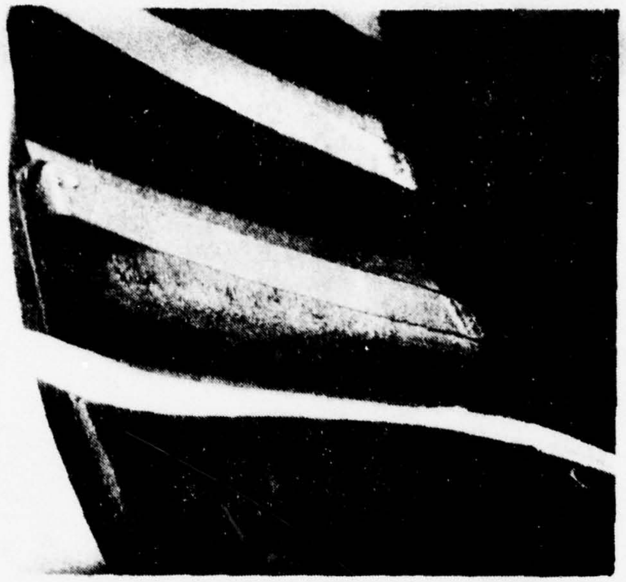

Figure E-114
Implant BHC-128
42-degree Gearbox Gear P/N 204-040-500-10 S/N 1269-10
Natural Category "C" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test Cell	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		1/76	48.0	Removal Limit Confidence Test
						48.0	Total Time

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Figure E-115
Implant BHC-130
Transmission Tail Rotor Output Gear P/N 204-040-104, S/N A12-14468
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit Confidence Test
X		X			2/76	90.1	Removal Limit Confidence Test
						181.9	Total Time

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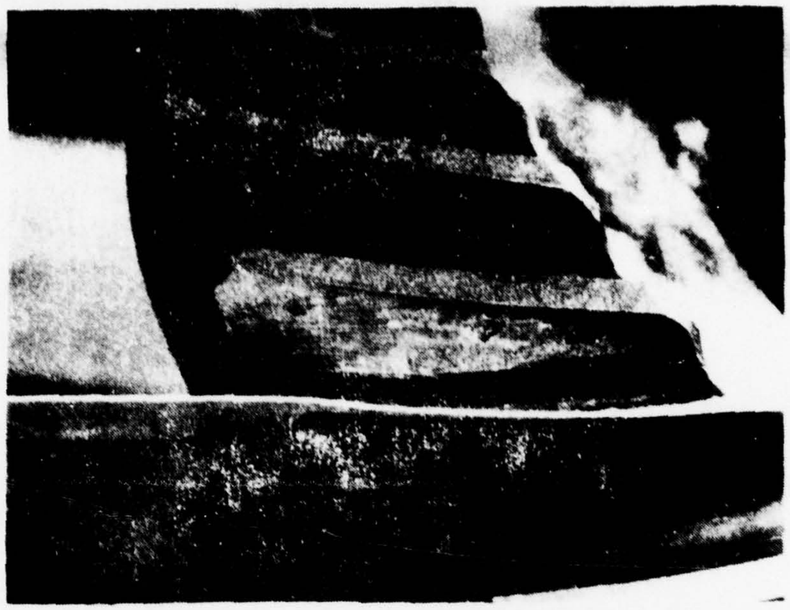

Figure E-116
Implant BHC-131
Transmission Sump Pinion P/N 204-040-103, S/N B12-5959
Natural Category "D" Debris (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit
X		X			2/76	90.1	Confidence Test
						181.9	Total Time

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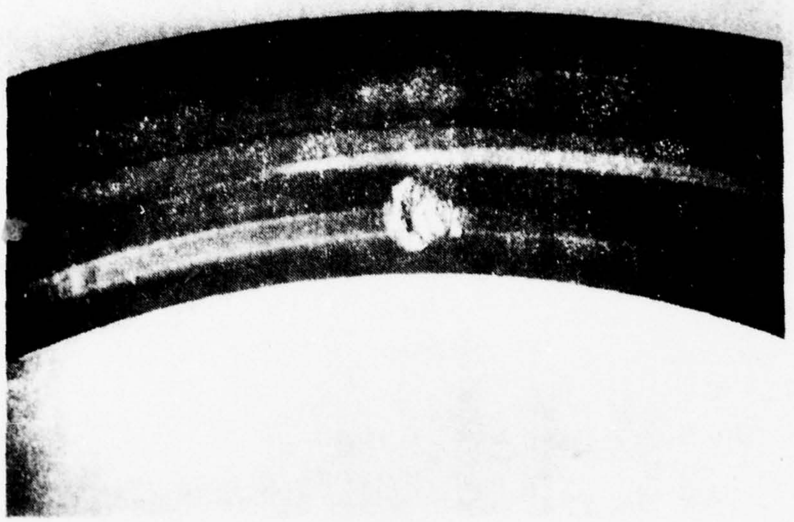

Figure E-117
Implant BHC-132
Ball Bearing P/N 204-040-136, S/N A2895
Natural Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			3/76	102.0	Removal Limit Confidence Test
	X	X			7/76	3.9	Prototype Testing
	X	X			8/76	1.1	Prototype Testing
	X	X			10/76	13.7	Prototype Testing
						120.7	Total Time

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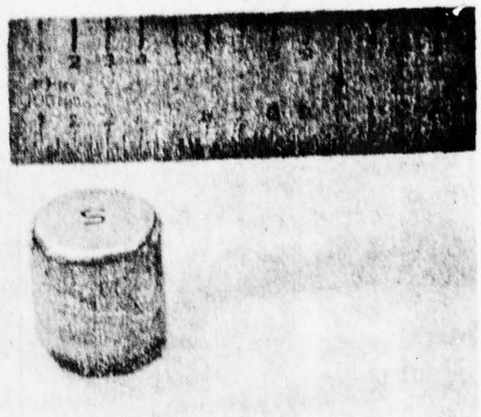

Figure E-118
Implant BHC-133
Roller Bearing P/N 204-040-725
Natural Category "D" Roller Spall

Installation History

(Not tested)

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Figure E-119
Implant BHC-134
42-degree Gearbox Pinion P/N 204-040-500-9, S/N B13-14313
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
X			X		3/76	102.0	Removal Limit Confidence Test
	X		X		7/76	5.8	Prototype Testing
	X		X		8/76	1.1	Prototype Testing
	X		X		9/76	4.6	Prototype Testing
	X		X		11/76	6.6	Prototype Testing
						120.1	Total Time

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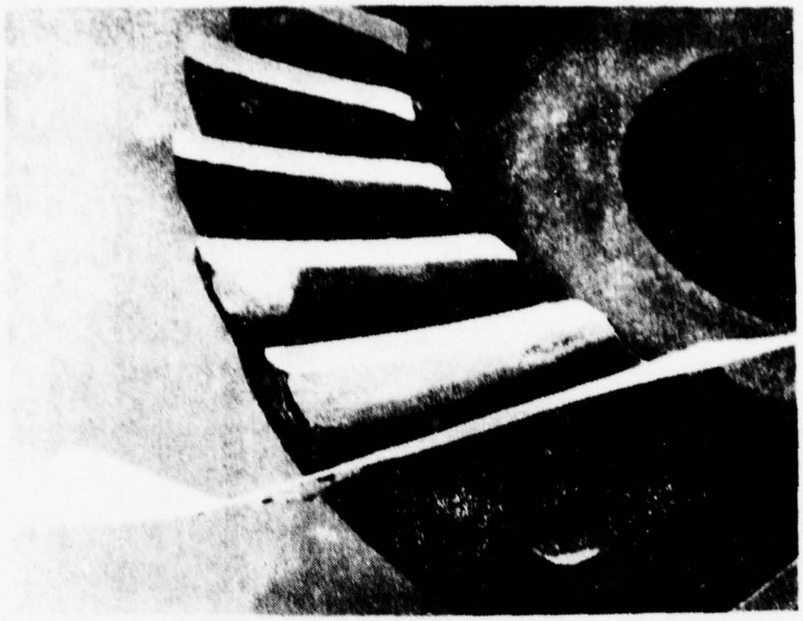

Figure E-120
Implant BHC-135
42-degree Gearbox Gear P/N 204-040-500-10, S/N SLP-405
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		3/76	102.0	Removal Limit Confidence Test
	X		X		7/76	5.8	Prototype Testing
	X		X		8/76	1.1	Prototype Testing
	X		X		9/76	4.6	Prototype Testing
	X		X		11/76	6.6	Prototype Testing
						120.1	Total Time

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Figure E-121
Implant BHC-136
90-degree Gearbox Pinion P/N 204-040-400, S/N A13-10430
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	3/76	58.1	Removal Limit Confidence Test
						58.1	Total Time

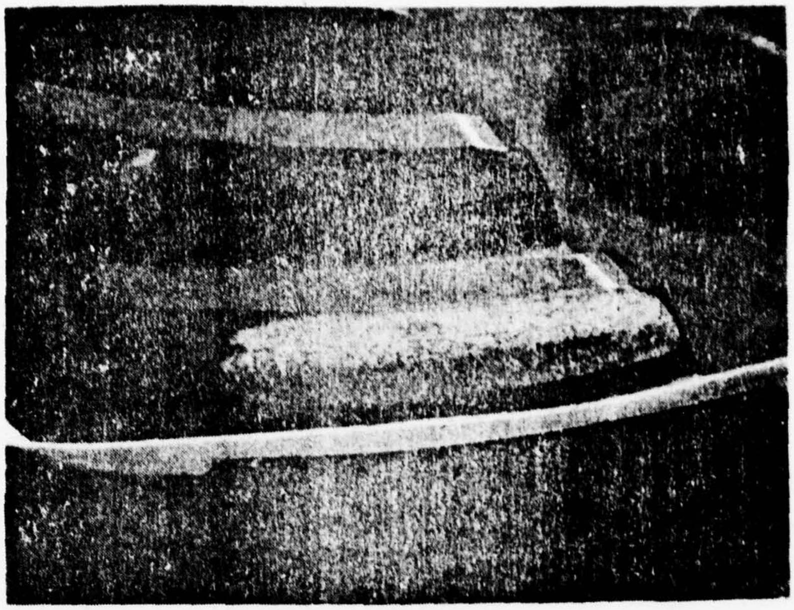

Figure E-122
Implant BHC-137
90-degree Gearbox Gear P/N 204-040-401, S/N A13-10655
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	3/76	58.1	Removal Limit Confidence Test
						58.1	Total Time

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Figure E-123
Implant BHC-138
Transmission Input Pinion P/N 204-040-700, S/N AR-12214
Natural Category P/N "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X		X	3/76	102.0	Removal Limit Confidence Test
	X	X			6/76	5.4	Prototype Testing
	X	X			6/76	1.0	Prototype Testing
	X	X			10/76	4.5	Prototype Testing
						112.9	Total Time

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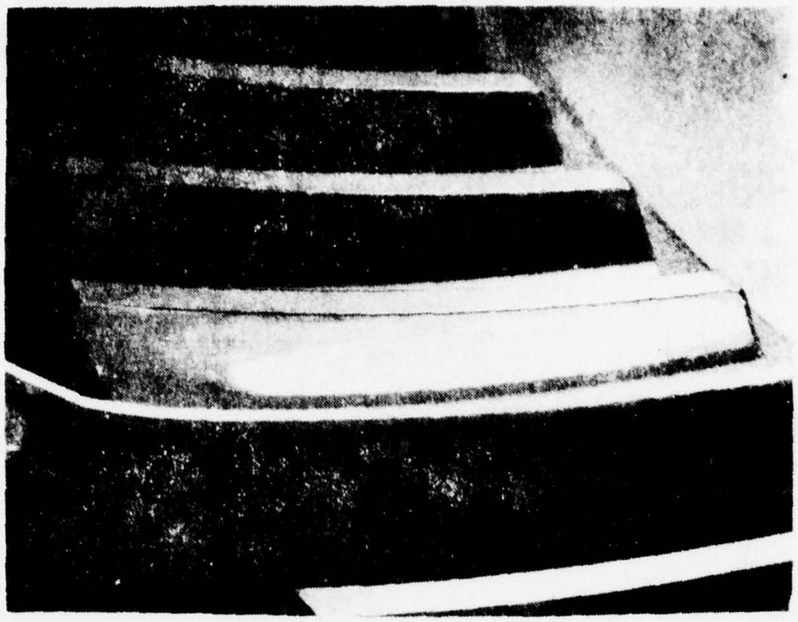

Figure E-124
Implant BHC-139
Transmission Input Gear P/N 204-040-701, S/N A12-11561
Natural Category "D" Score (Every Tooth)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X		X	3/76	102.0	Removal Limit Confidence Test
	X	X			6/76	5.4	Prototype Testing
					6/76	1.0	Prototype Testing
	X	X			10/76	4.5	Prototype Testing
						112.9	Total Time

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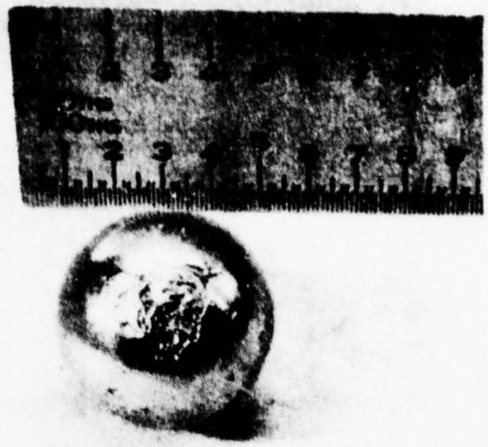

Figure E-125
Implant MAIC-001
Ball Bearing P/N 204-040-143, S/N 91851
Fatigue Induced Category "D" Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	1/76	91.8	Removal Limit Confidence Test
	X			X	6/76	5.4	Prototype Testing
	X			X	6/76	1.0	Prototype Testing
	X		X		6/76	5.6	Prototype Testing
	X		X		7/76	1.0	Prototype Testing
						104.8	Total Time

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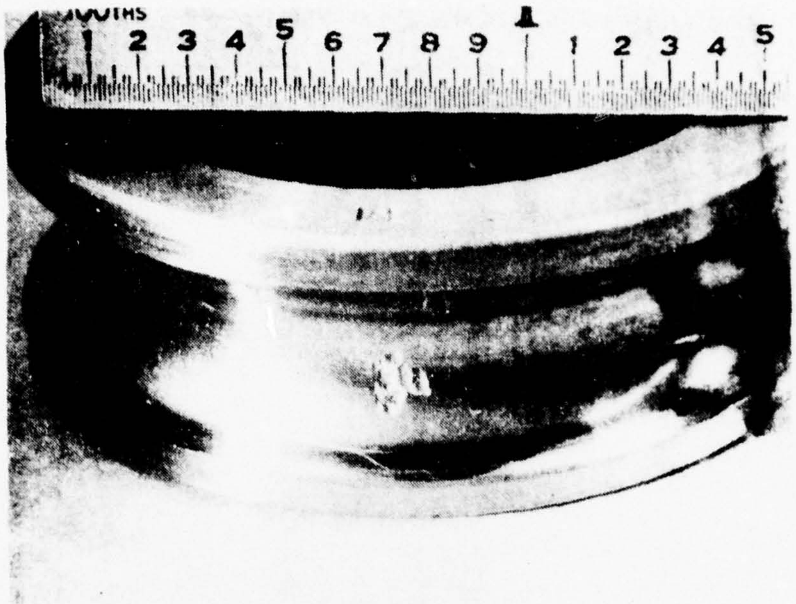

Figure E-126
Implant MAIC-002
Ball Bearing P/N 204-040-143, S/N 78850-1
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		1/76	91.8	Removal Limit Confidence Test
	X			X	8/76	4.4	Prototype Test
						96.2	Total Time

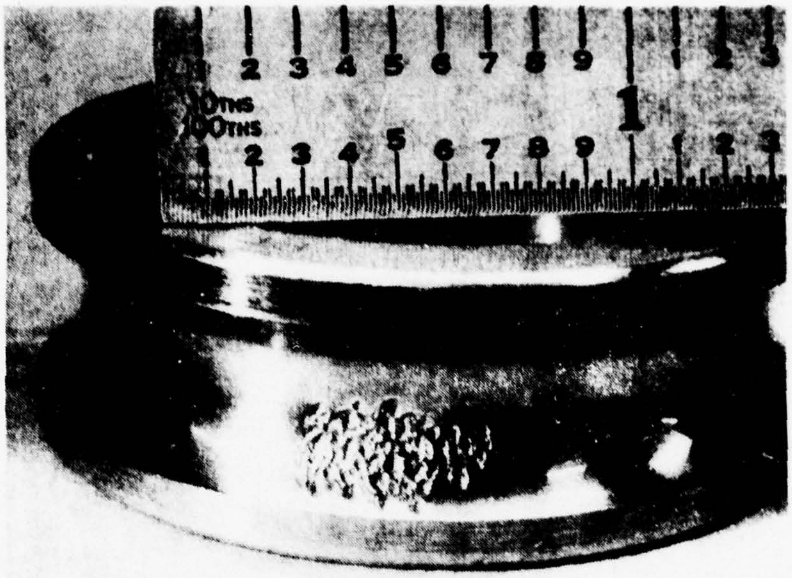

Figure E-127
Implant MAIC-003
Ball Bearing P/N 204-040-143, S/N A6379
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit
X				X	3/76	43.9	Confidence Test
	X			X	6/76	3.6	Prototype Testing
	X			X	7/76	1.0	Prototype Testing
	X		X		10/76	9.2	Prototype Testing
						149.5	Total Time

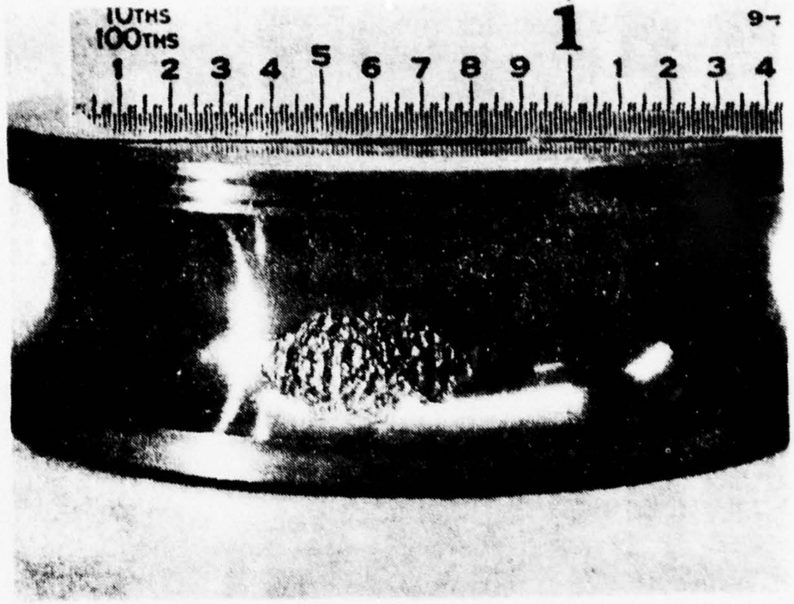

Figure E-128
Implant MAIC-004
Ball Bearing P/N 204-040-143, S/N 63715
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit Confidence Test
	X		X		5/76	6.0	Prototype Testing
	X		X		6/76	0.6	Prototype Testing
	X			X	7/76	6.0	Prototype Testing
	X			X	8/76	2.1	Prototype Testing
						106.5	Total Time

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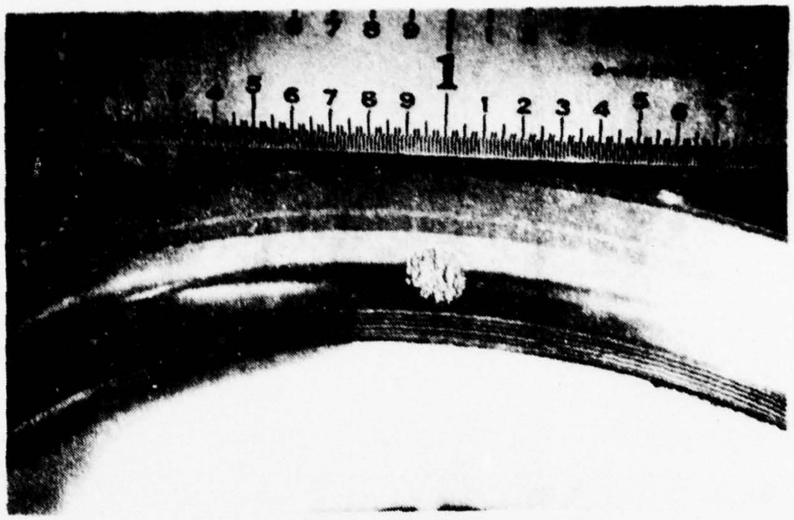

Figure E-129
Implant MAIC-005
Ball Bearing P/N 204-040-143, S/N 27921
Fatigue Induced Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	1/76	62.1	Removal Limit Confidence Test
						62.1	Total Time

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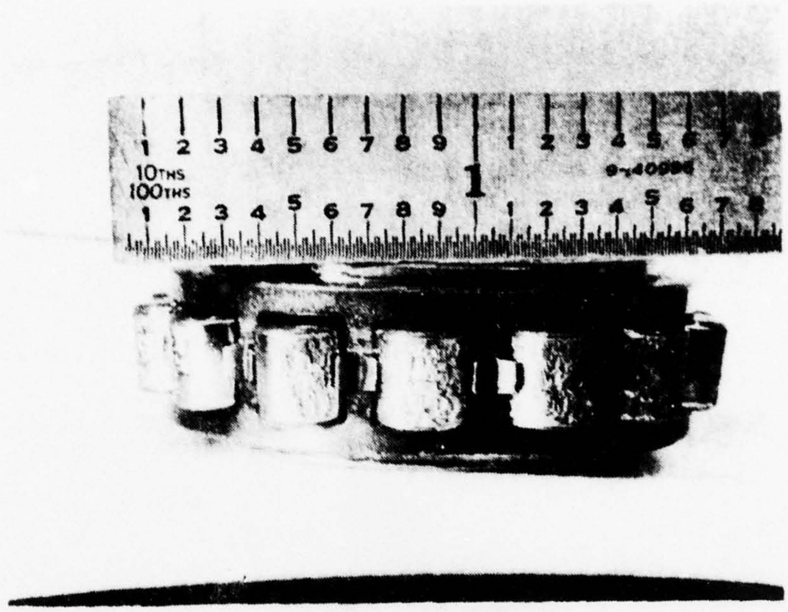

Figure E-130
Implant MAIC-006
Roller Bearing P/N 204-040-406, S/N 2450
Fatigue Induced Category "D" Roller Spall (Every Roller)

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	1/76	91.8	Removal Limit
X				X	3/76	43.9	Confidence Test
						135.7	Total Time

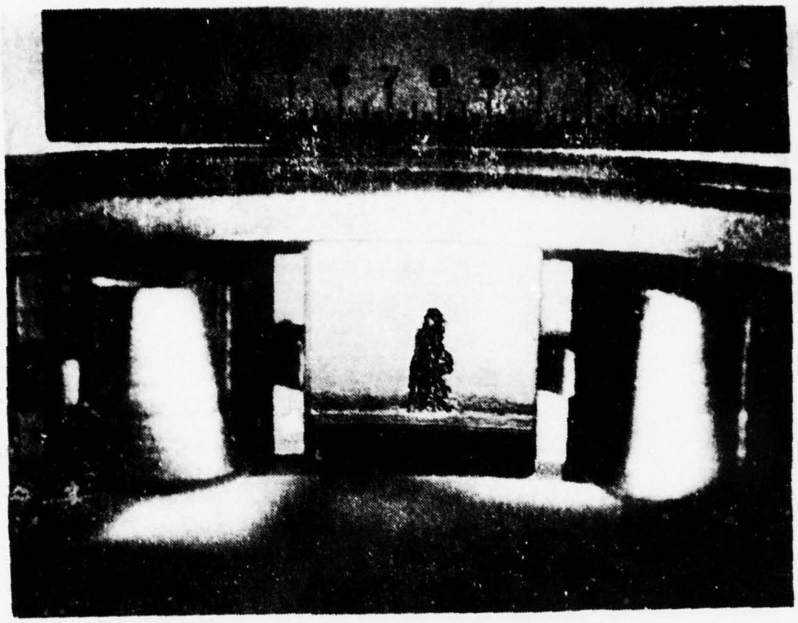

Figure E-131
Implant MAIC-007
Roller Bearing P/N 204-040-310, P/N 100446
Fatigue Induced Category "C" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		1/76	91.8	Removal Limit
X		X			2/76	90.1	Confidence Test
X			X		3/76	102.0	
						283.9	Total Time

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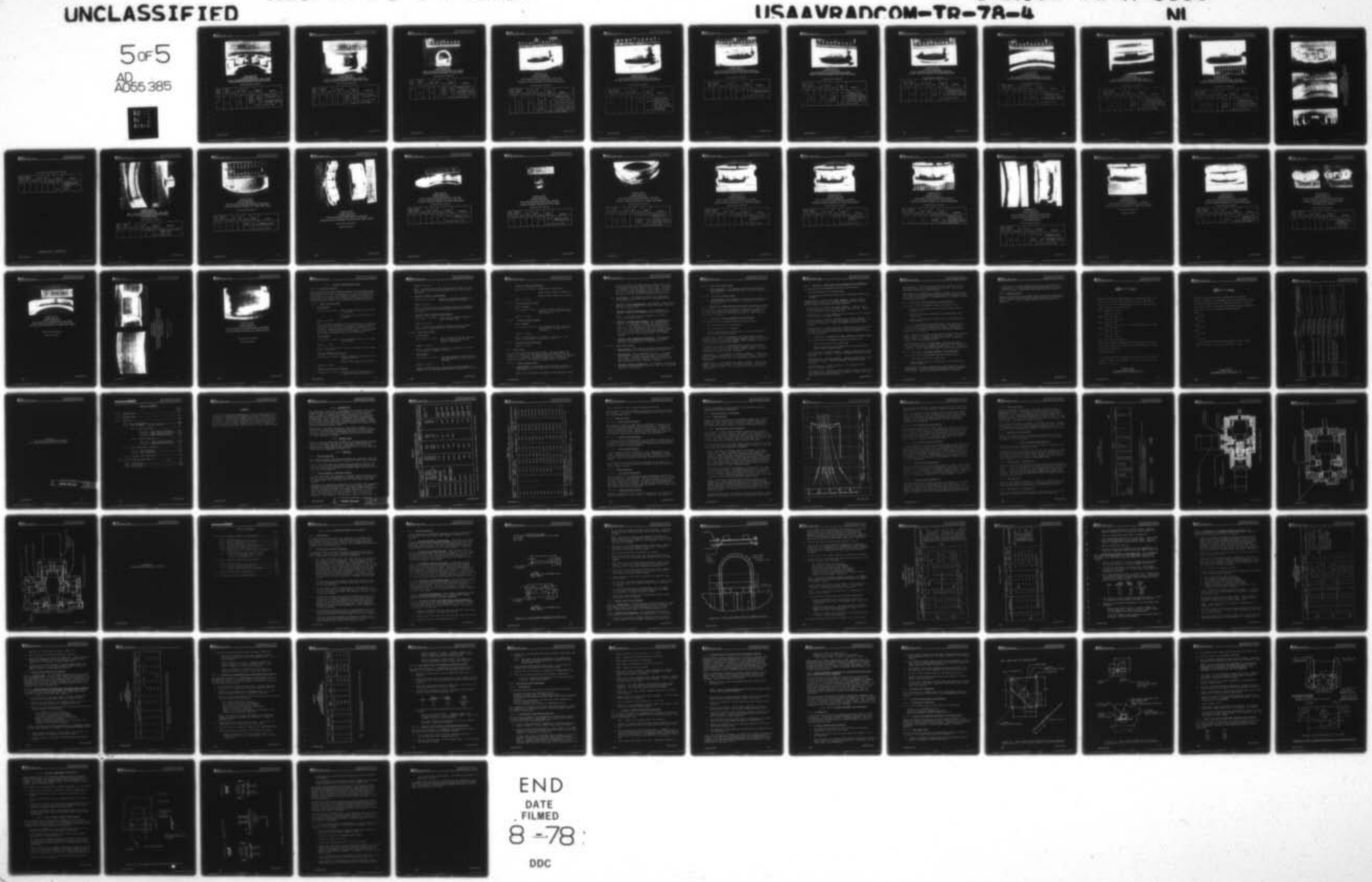

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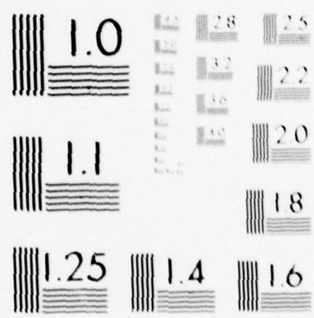

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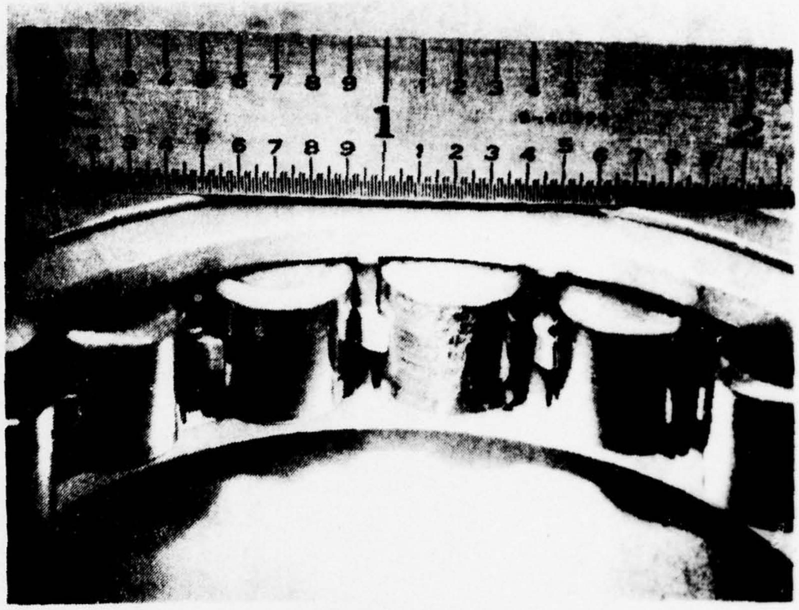

Figure E-132
Implant MAIC-008
Roller Bearing P/N 204-040-310, P/N 113329
Fatigue Induced Category "D" Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		1/76	91.8	Removal Limit
X		X			2/76	90.1	Confidence Test
X			X		3/76	102.0	
	X		X		5/76	5.0	Prototype Testing
	X		X		6/76	1.0	Prototype Testing
						289.0	Total Time

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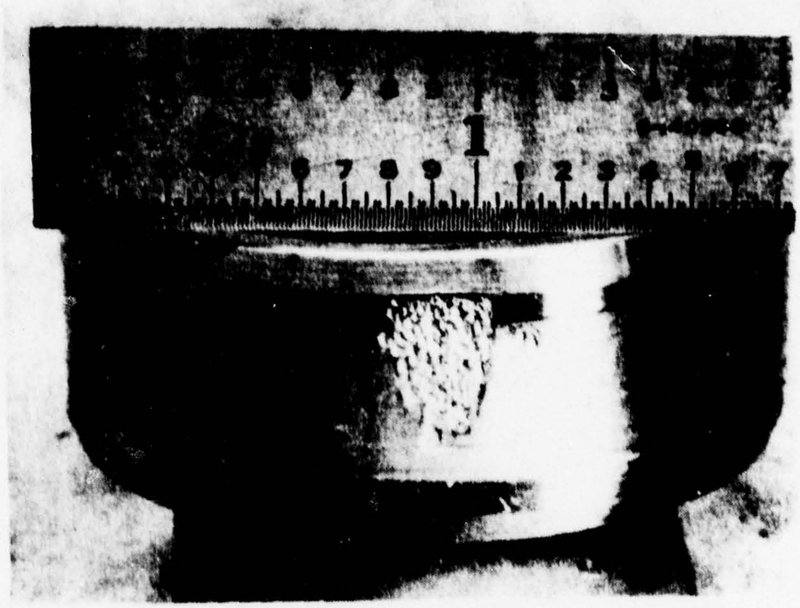

Figure E-133
Implant MAIC-009
Roller Bearing P/N 204-040-310, S/N 3139
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit
X			X	X	2/76	90.1	Confidence Test
X		X			3/76	102.0	
	X		X		10/76	6.8	Prototype Test
						290.7	Total Time

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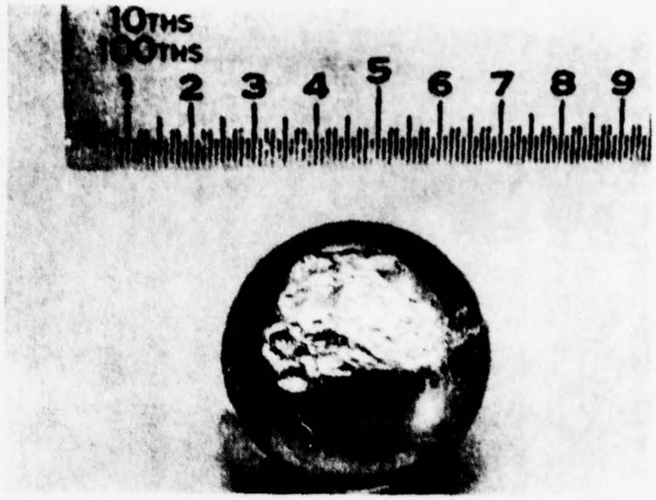

Figure E-134
Implant MAIC-010
Ball Bearing P/N 204-040-143, S/N 1920D
Fatigue Indiced Category "D" Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		2/76	90.1	Removal Limit
X		X			3/76	102.0	Confidence Test
	X		X		8/76	9.9	Prototype Testing
	X		X		8/76	0.8	Prototype Testing
	X			X	9/76	4.8	Prototype Testing
						207.6	Total Time

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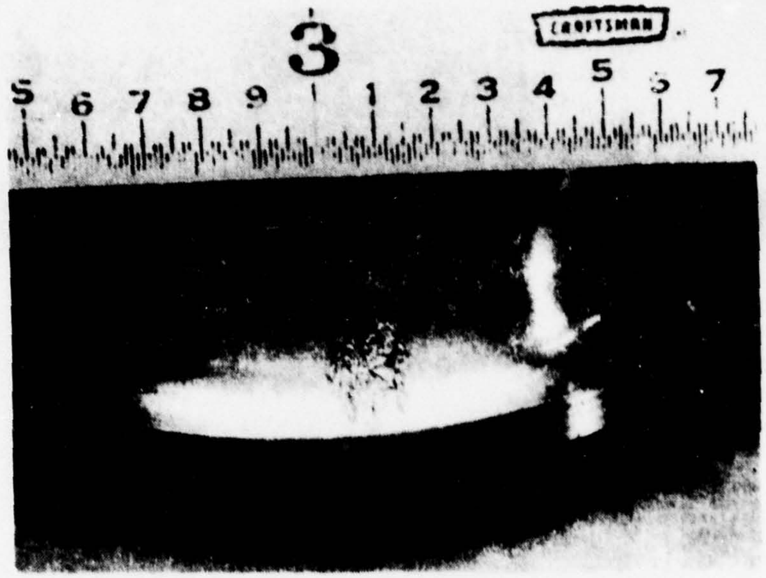

Figure E-135

Implant MAIC-011

Ball Bearing P/N 204-040-143, S/N 1175K

Fatigue Induced Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			1/76	91.8	Removal Limit Confidence Test
	X		X		5/76	6.0	Prototype Testing
	X		X		6/76	0.6	Prototype Testing
	X			X	7/76	6.0	Prototype Testing
	X			X	8/76	2.1	Prototype Testing
	X			X	10/76	9.2	Prototype Testing
						116.7	Total Time

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Figure E-136
Implant BHC-012
Ball Bearing P/N 204-040-143, S/N 9051
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	2/76	90.1	Removal Limit Confidence Test
X		X			3/76	102.0	Removal Limit Confidence Test Unit Not Serviceable For Additional Testing
						192.1	Total Time

Figure E-137
Implant MAIC-013
Ball Bearing P/N 204-040-143, S/N 65583-1
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			2/76	90.1	Removal Limit Confidence Test
						90.1	Total Time

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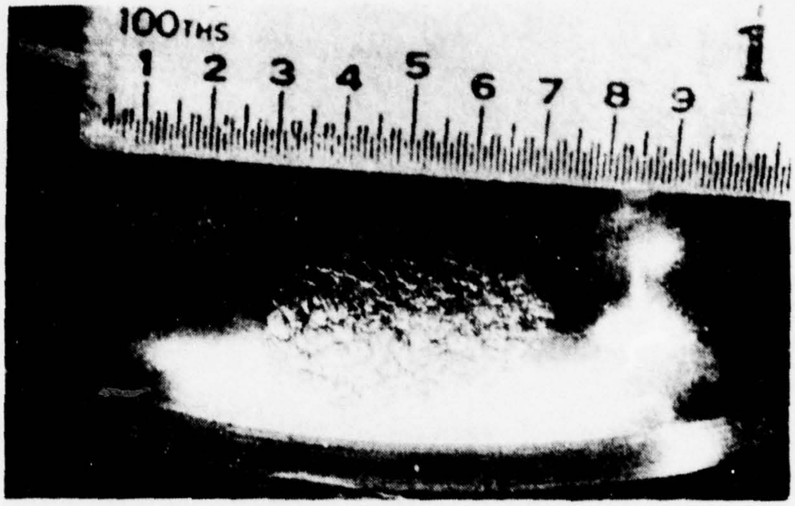

Figure E-138
Implant MAIC-014
Ball Bearing P/N 204-040-143, S/N 58401
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			2/76	90.1	Removal Limit Confidence Test
	X		X		7/76	4.8	Prototype Testing
	X		X		7/76	1.7	Prototype Testing
	X		X		9/76	6.2	Prototype Testing
	X			X	10/76	5.2	Prototype Testing
						108.0	Total Time

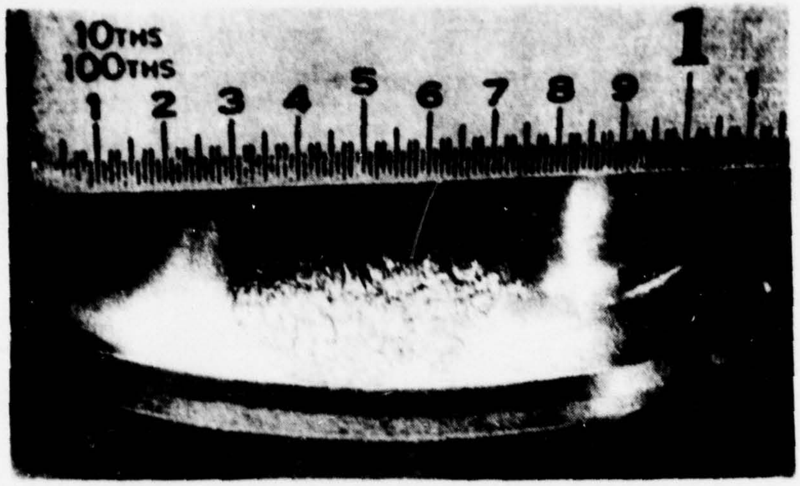

Figure E-139
Implant MAIC-015
Ball Bearing P/N 204-040-143, S/N A1030
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			2/76	90.1	Removal Limit Confidence Test
	X		X		7/76	5.3	Prototype Testing
	X		X		8/76	1.1	Prototype Testing
						96.5	Total Time

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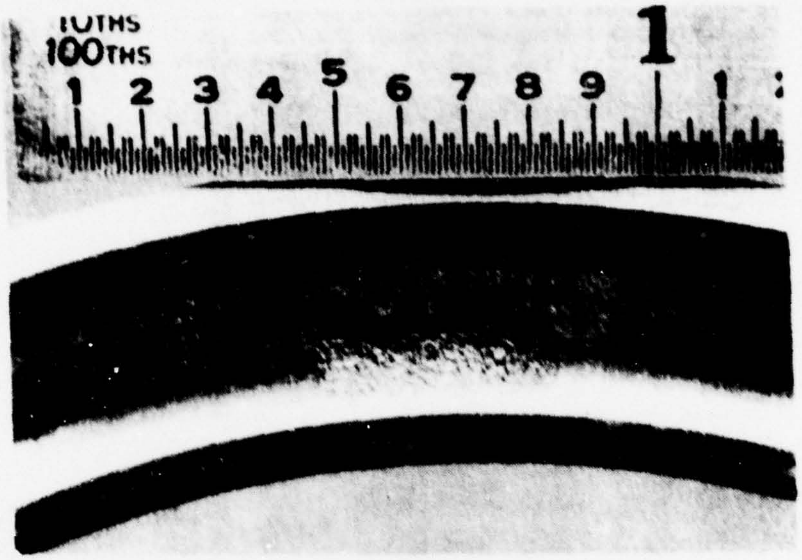

Figure E-140
Implant MAIC-016
Ball Bearing P/N 204-040-424, S/N 5028
Fatigue Induced Category "D" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	2/76	90.1	Removal Limit Confidence Test
	X			X	7/76	5.2	Prototype Testing
	X			X	7/76	1.0	Prototype Testing
						96.3	Total Time

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Figure E-141
Implant MAIC-017
Ball Bearing P/N 204-040-245, S/N 782
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			2/76	90.1	Removal Limit Confidence Test
	X	X			8/76	6.5	Prototype Testing
	X	X			8/76	1.0	Prototype Testing
	X	X			11/76	8.5	Prototype Testing
						106.1	Total Time

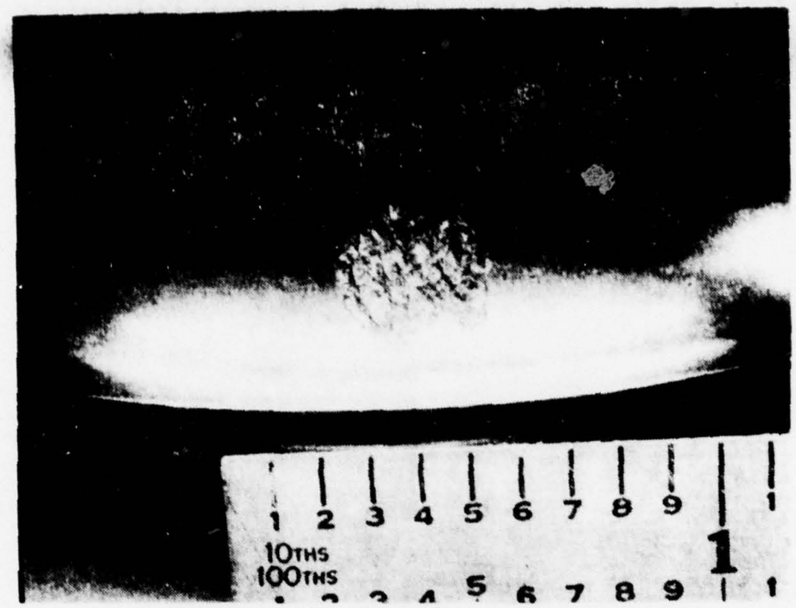

Figure E-142
Implant MAIC-018
Ball Bearing P/N 205-040-246, S/N 3969
Fatigue Induced Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X		X			2/76	90.1	Removal Limit Confidence Test
	X	X			7/76	6.1	Prototype Testing
	X	X			8/76	1.1	Prototype Testing
	X	X			10/76	5.3	Prototype Testing
						102.6	Total Time

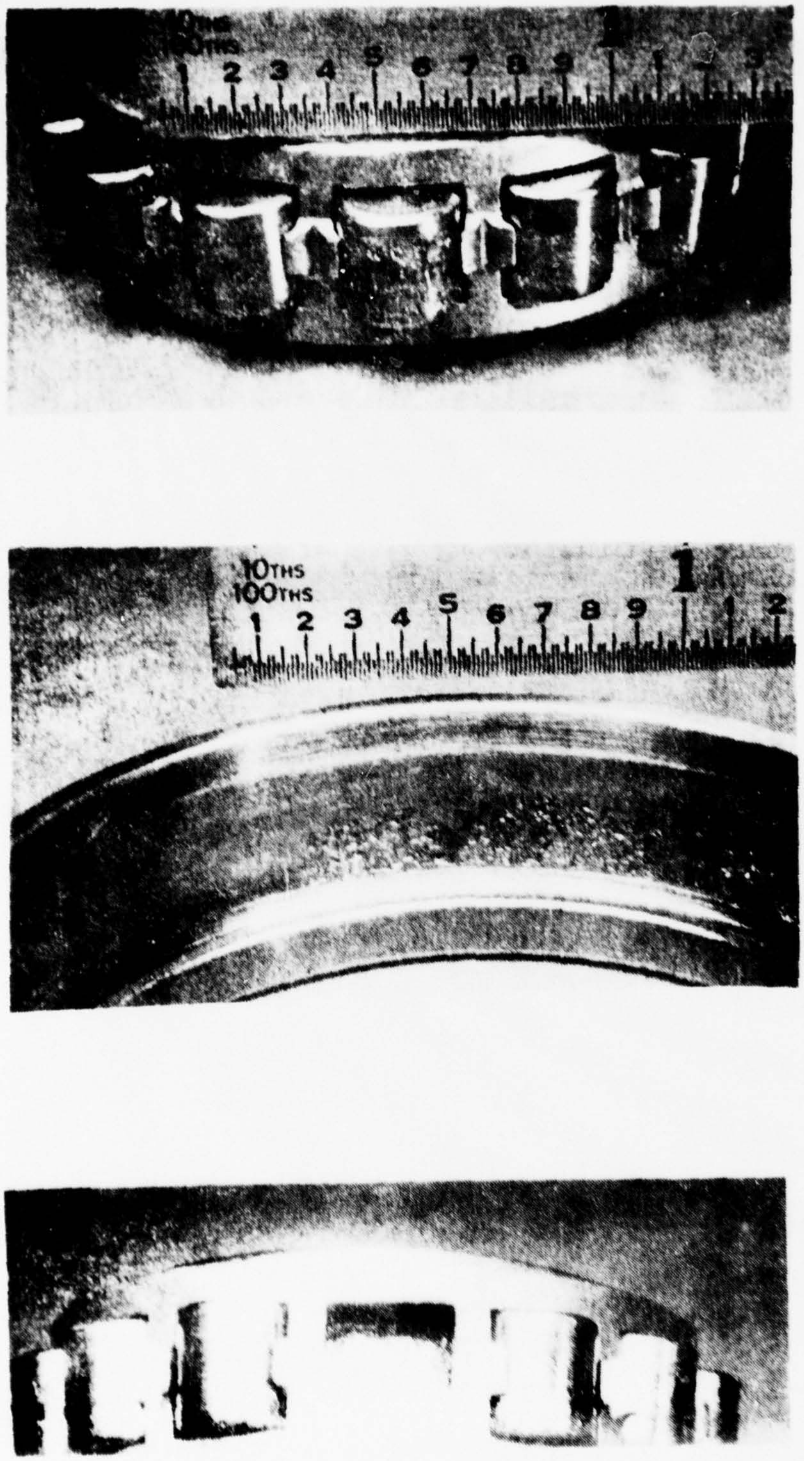

Figure E-143
Implant MAIC-019
Roller Bearing P/N 204-040-406, S/N 2163
Fatigue Induced Category "D" Inner Race,
Outer Race and Roller Spall

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MAIC-019 Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X				X	2/76	90.1	Removal Limit Confidence Test Failed
						90.1	Total

Figure E-143. (Continued)

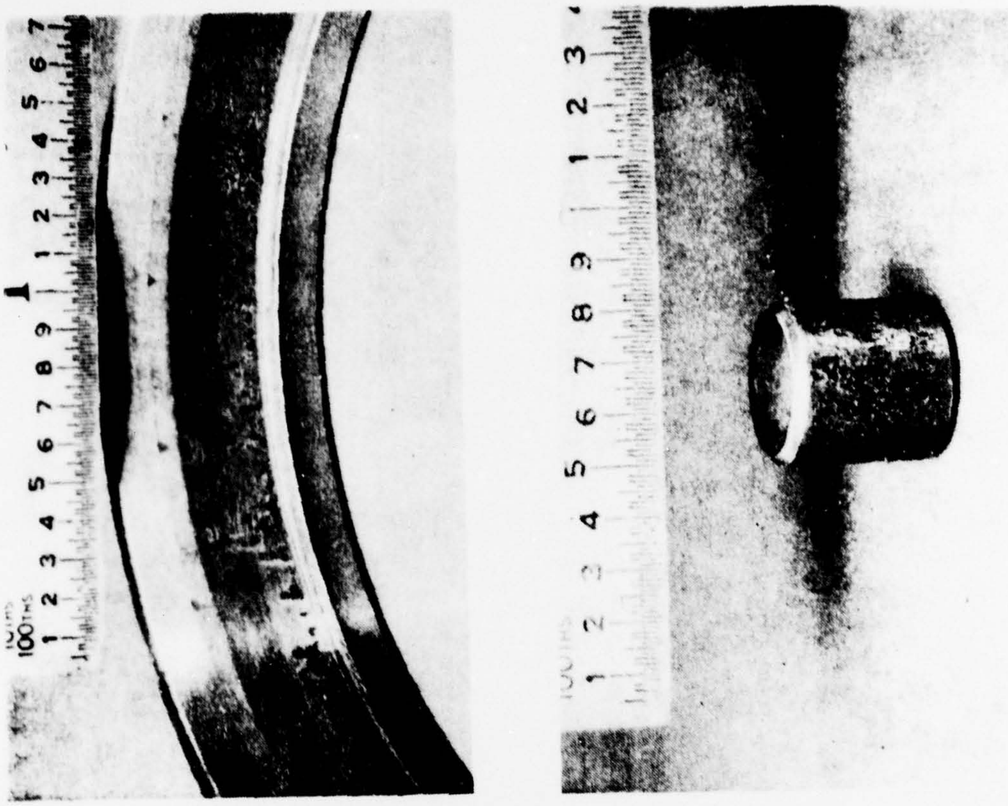

Figure E-144
Implant MAIC-020
Roller Bearing P/N 204-040-406, S/N 29950
Fatigue Induced Category "D" Outer Race, and Roller Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	2/76	90.1	Removal Limit Confidence Test
						90.1	Total Time

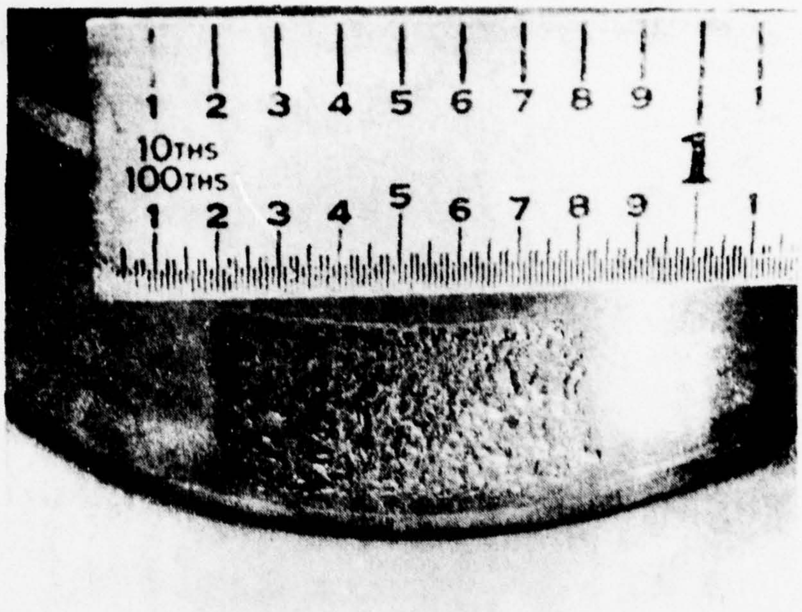

Figure E-145
Implant MAIC-021
Roller Bearing P/N 204-040-310, S/N 107507
Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		2/76	90.1	Removal Limit
		X			3/76	102.0	Confidence Test
						192.1	Total Time

Figure E-146

Implant MAIC-022

Roller Bearing P/N 204-040-310, S/N H701

Fatigue Induced Category "D" Inner Race Spall (360°)

Installation History

(Never Tested)

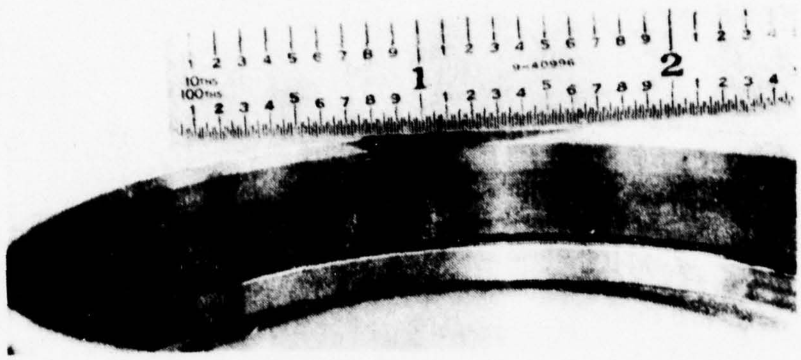

Figure E-147

Implant MAIC-023

Roller Bearing P/N 204-040-407, S/N 5282

Fatigue Induced Category "D" Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X				X	3/76	102.0	Removal Limit Confidence Test
						102.0	Total Time

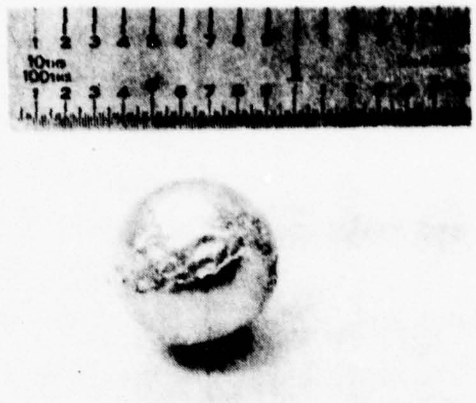

Figure E-148

Implant MAIC-024

Ball Bearing P/N 204-040-245, S/N 947

Fatigue Induced Category "D" Ball Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
X		X			3/76	102.0	Removal Limit Confidence Test
						102.0	Total Time

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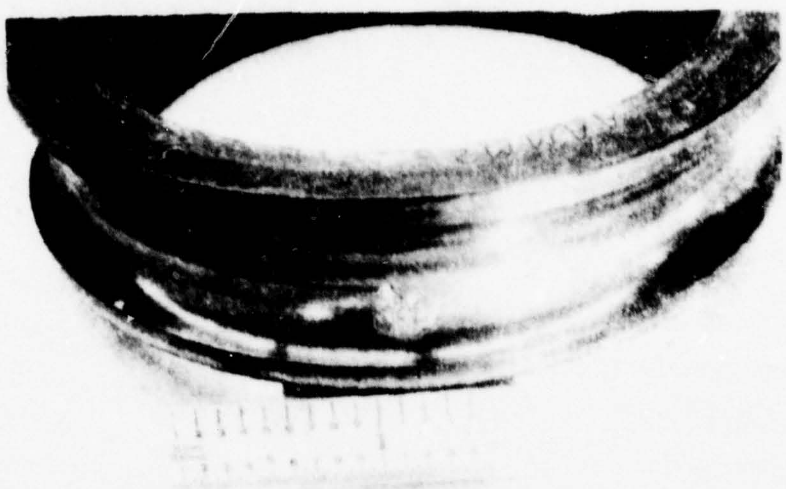

Figure E-149

Implant MAIC-025

Ball Bearing P/N 205-040-246, S/N 1158

Fatigue Induced Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^o GB	90^o GB	Date	Test Hours	Remarks
X		X			3/76	102.0	Removal Limit Confidence Test
	X	X			6/76	4.2	Prototype Testing
	X	X			7/76	1.0	Prototype Testing
	X	X			8/76	2.4	Prototype Testing
						109.6	Total Time

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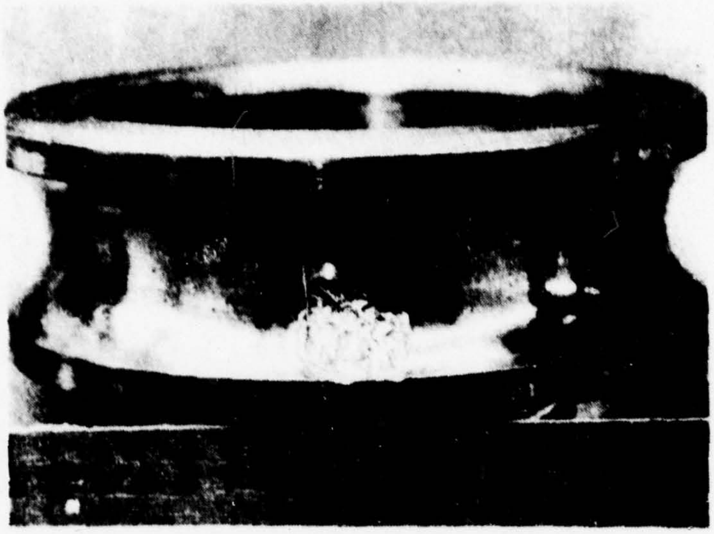

Figure E-150

Implant MAIC-026

Ball Bearing P/N 204-040-143, S/N 409H

Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X				X	3/76	58.1	Removal Limit Confidence Test Failed
						58.1	Total Time

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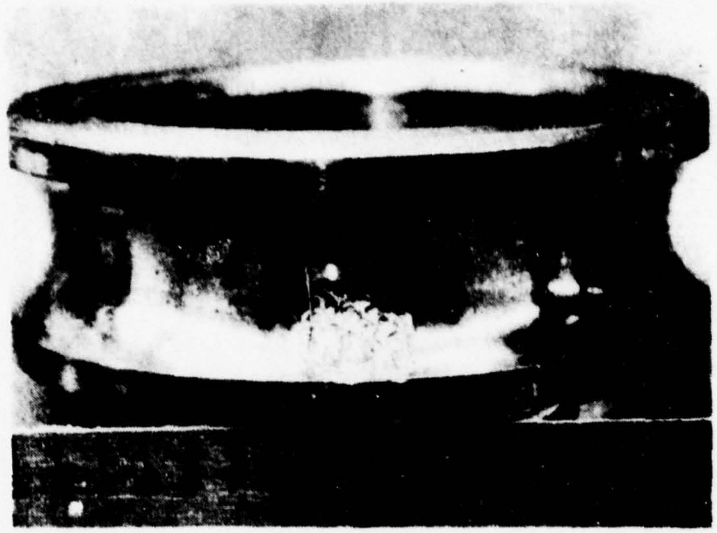

Figure E-150

Implant MAIC-026

Ball Bearing P/N 204-040-143, S/N 409H

Fatigue Induced Category "D" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X				X	3/76	58.1	Removal Limit Confidence Test Failed
						58.1	Total Time

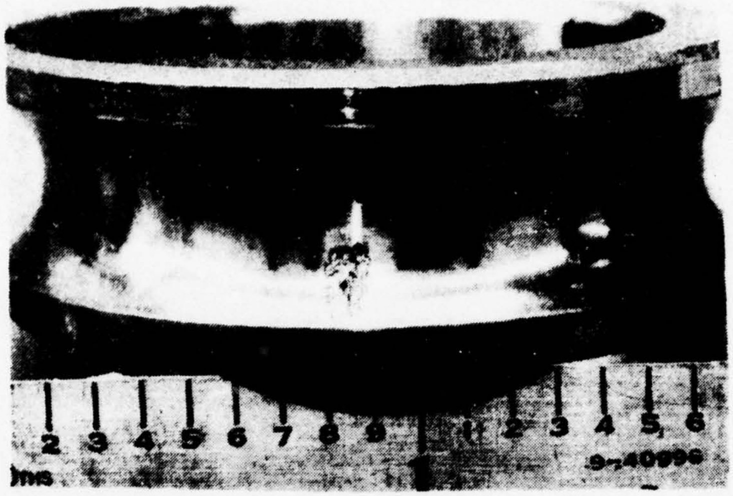

Figure E-151

Implant MAIC-027

Ball Bearing P/N 204-040-143 S/N A8076

Fatigue Induced Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X			X		3/76	102.0	Removal Limit Confidence Test
	X		X		6/76	4.5	Prototype Testing
	X		X		7/76	3.3	Prototype Testing
						109.8	Total Time

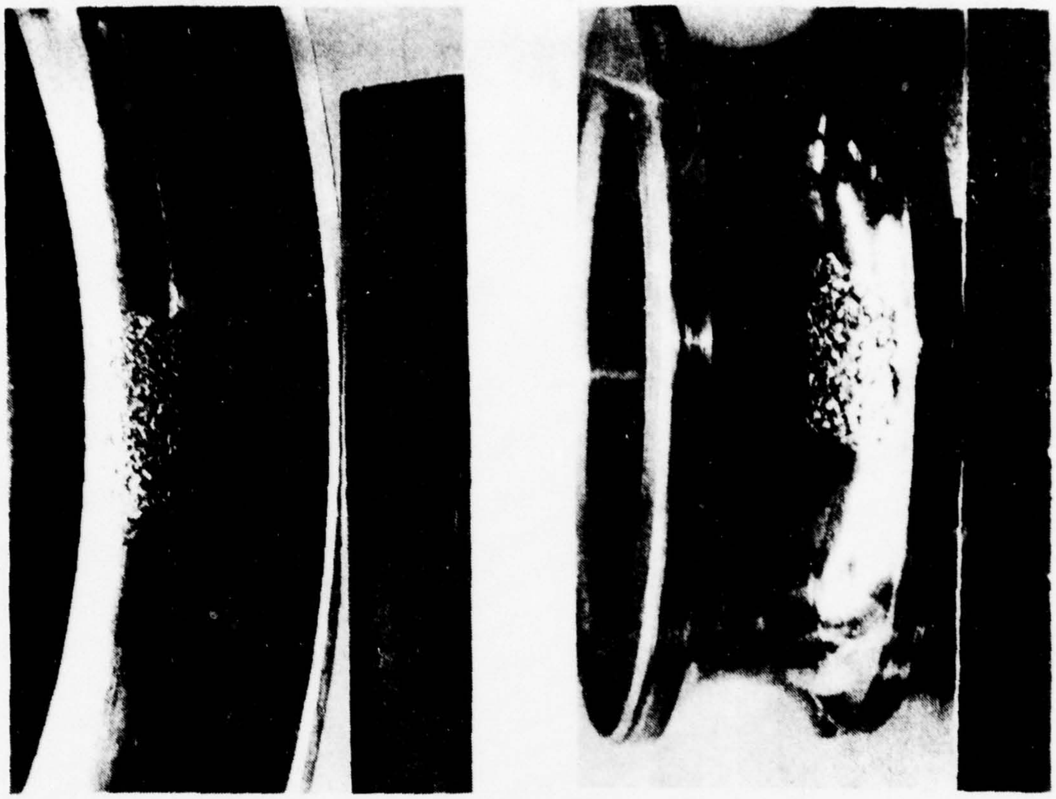

Figure E-152

Implant MAIC-028

Ball Bearing P/N 204-040-143 S/N 33337

Fatigue Induced Category "D" Inner and Outer Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42^{o} GB	90^{o} GB	Date	Test Hours	Remarks
X			X		3/76	102.0	Removal Limit Confidence Test
	X	X			4/76	9.0	Prototype Testing
	X	X			7/76	0.8	Prototype Testing
						111.8	Total Time

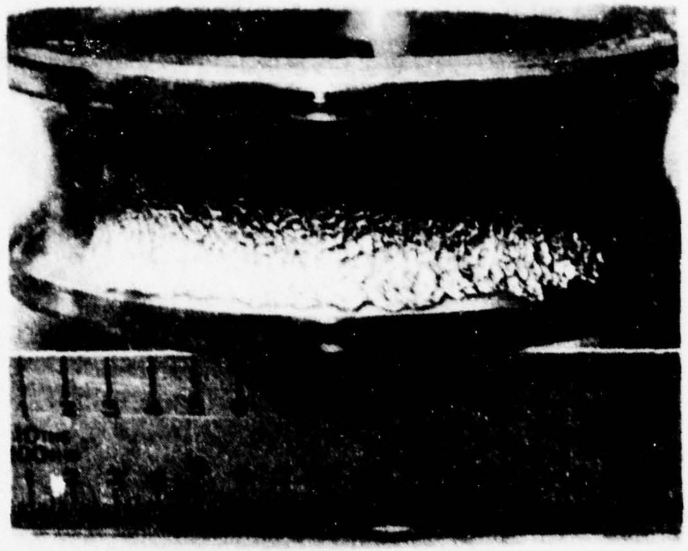

Figure E-153

Implant MAIC-029

Ball Bearing P/N 204-040-143, S/N 59352

Fatigue Induced Category "D" Inner Race Spall

Installation History

(Never Tested)

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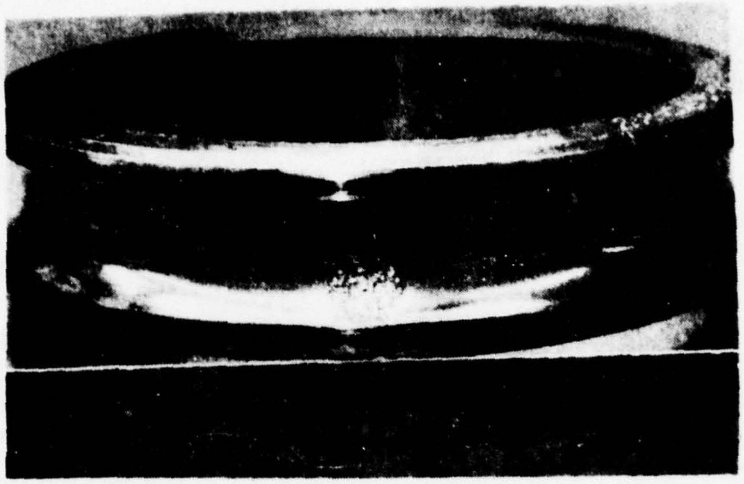

Figure E-154

Implant MAIC-030

Ball Bearing P/N 204-040-424, S/N 29288

Fatigue Induced Category "C" Inner Race Spall

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	3/76	102.0	Removal Limit Confidence Test
	X			X	10/76	6.8	Prototype Test
						108.8	Total Time

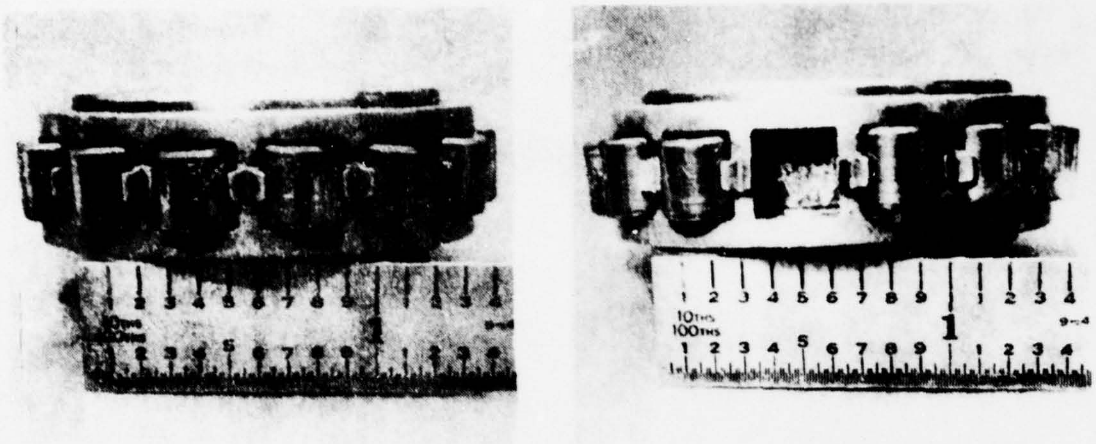

Figure E-155

Implant MAIC-031

Roller Bearing P/N 204-040-406, S/N 3351

Fatigue Induced Category "D" Inner Race and Roller (3) Spalls

Installation History

BHT Test Cell	ADTA Test A/C	Xmsn	42° GB	90° GB	Date	Test Hours	Remarks
X				X	3/76	58.1	Removal Limit Confidence Test Considered Unserviceable
						58.1	Total Time

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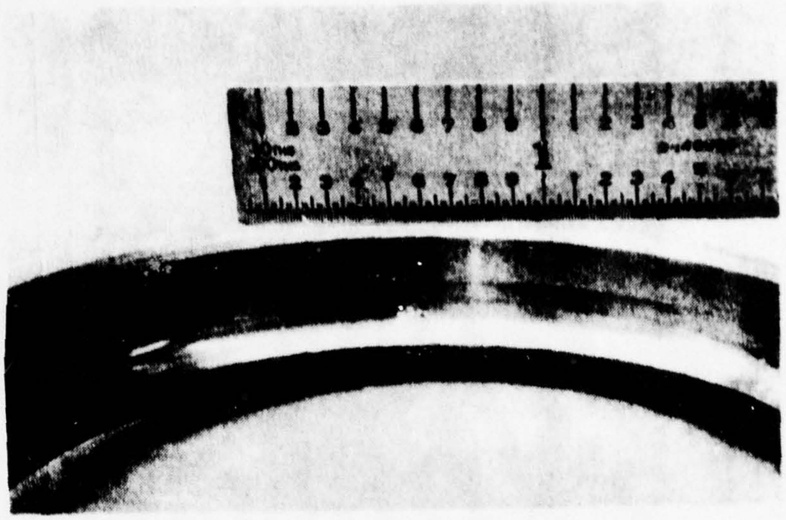

Figure E-156

Implant MAIC-032

Ball Bearing P/N 204-040-424, S/N 22890

Fatigue Induced Category "C" Outer Race Spall

Installation History

(Never Tested)

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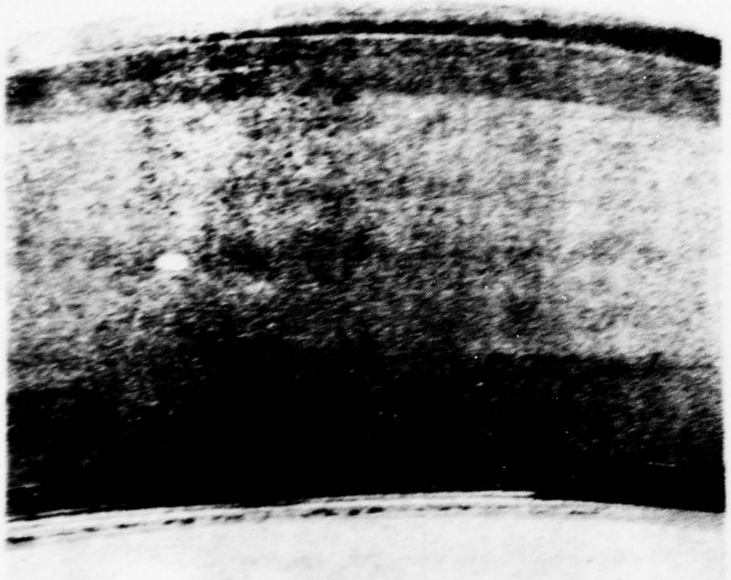

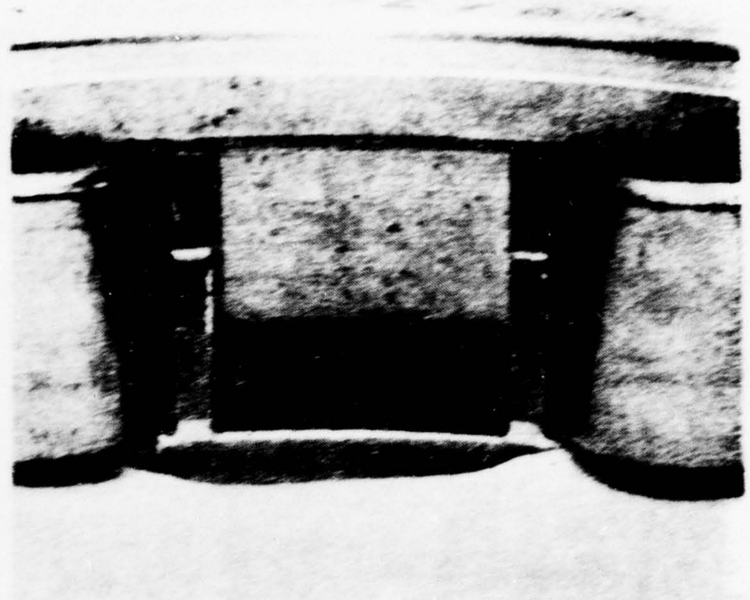

Figure E-157

Implant MAIC-033

Roller Bearing P/N 204-040-310 S/N 16102

Fatigue Induced Category "B" Inner and Outer Race Pits

Installation History

(Never Tested)

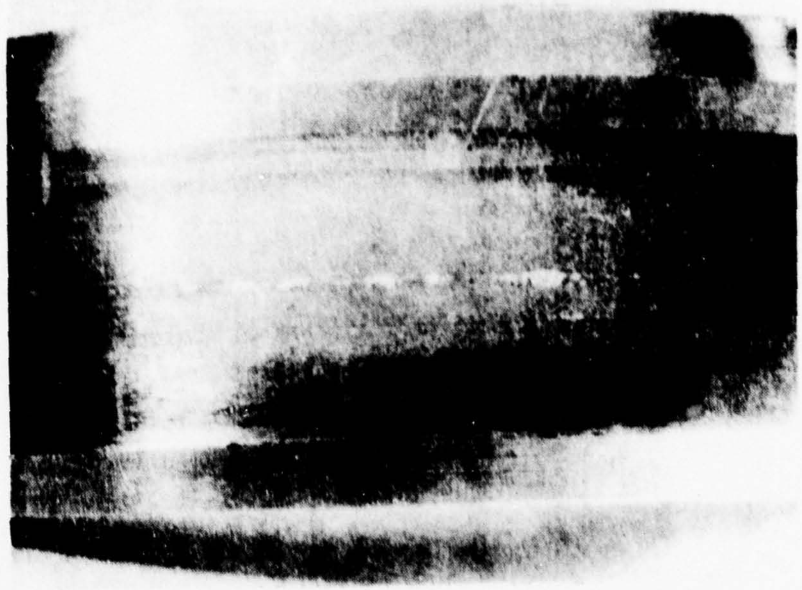

Figure E-158

Implant MAIC-034

Roller Bearing P/N 204-040-310, S/N 114052

Fatigue Induced Category "B" Inner Race Pit

Installation History

(Never Tested)

E-2.0 IMPROPER INSTALLATION TESTS

E-2.1 Airesearch Proposal

Airesearch Manufacturing Company document "Proposed Maintenance Installation Error Tests," 28 April 1975, was received at BHT from AVSCOM for review. The document provided an estimate for a test effort to evaluate the vibration signatures of specified maintenance installation errors and their detectability by the AIDAPS vibration system. The proposed tests were as follows:

E-2.1.1 Hanger Bearing Tests

A. Loose V-Band

Description of Error: Loose forward V-band at two levels of looseness.

Loose aft V-band at two levels of looseness.

Number of Tests: 4

Note: Separate forward and aft V-band errors are planned because of the difference in coupling design at these two locations. First level of looseness is defined as the degree of looseness that will cause pilot's notice through the pedal. The second level of looseness is defined as approximately one-half that of the first level.

B. Loose Hanger

Description of Error: Loose mounting bolts at two levels of looseness.

Number of Tests: 2

Note: The definition of levels of looseness is the same as for "A" above.

C. Improper V-Band Installation

Description of Error: Wrong V-band clamp orientation (0° instead of 90°).

Wrong V-band clamp bolt direction.

Number of Tests: 2

D. Improper Bearing Installation

Description of Error: Bearing installed backwards, but coupling correctly installed.

Number of Tests: 1

Note: Backward bearing may cause excessive wear on cage due to the ratchet action developed on cage during prior operation.

E. Improper Coupling Installation

Description of Error: Coupling installed backwards, but bearing installed correctly.

Number of Tests: 1

Note: Forward coupling is flexible and the aft coupling is rigid. Reversal of couplings may have adverse effect on bearing.

F. Improper Inner Coupling Installation

Description of Error: Loose inner coupling clamping on bearing inner race.

Number of Tests: 1

Note: Loose inner couplings clamping on bearing inner race may cause rapid wear out of the little shaft.

E-2.1.2. Short Shaft Tests

A. Loose V-Band

Description of Error: Loose V-band at both the forward and aft couplings and at two levels of looseness.

Number of Tests: 2

Note: The definition of levels of looseness is the same as described in Section E.2.1.1.A.

B. Misalignment

Description of Error: Improper alignment between engine and transmission, at two levels of severity.

Number of Tests: 2

Note: The definition of the levels of misalignment is similar to the looseness definition per Section E-2.1.1.A.

C. Improper V-band Installation

Description of Error: Mismatched V-band halves.

Wrong V-band clamp orientation

Wrong V-band clamp bolt direction

Number of Tests: 3

E-2.1.3. Tail Rotor Shaft Tests

A. Out of Balance

Description of Error: Improper/excessive balance patch peeling, at two levels of unbalance severity.

Number of Tests: 2

E-2.1.4. 42-degree Gearbox Tests

A. Loose Gearbox

Description of Error: Loose mounting bolts (all bolts at both ends) at two levels of looseness.

Number of Tests: 2

Note: The definition of levels of looseness is the same as described in Section E-2.1.1.A.

E-2.1.5 Baseline Data Collection

Number of Tests: 4

E-2.2 BHT Review

The proposed tests were reviewed by BHT. Review comments and Implant Part Inspection and Description Data Sheets outlining "Improper Installation" procedures required to conduct the proposed testing were submitted to AVSCOM per BHT Letter 81:JVH:peb-130, dated 16 June 1975. The review is summarized as follows:

E-2.2.1. Hanger Bearing Tests

A. Loose V-Band - The Improper Installation procedures are contained in Procedure BHC-II#2, described herein in Section E-2.3.

Note: The "looseness" described in the Improper Instal-

lation procedures is quantified by halving the torque requirements and then going to zero torque. The degree of looseness that will cause "pilot's notice through the pedals" is not definable at this time. To quantify this as a positive measurement would require a test designed to survey a group of helicopters and pilots.

B. Loose Hanger - The Improper Installation procedures are outlined in Procedure BHC-II#1, described herein in Section E-2.3.

C. Improper V-Band Installation - The Improper Installation procedures are outlined in Procedure BHC-II#2, described herein in Section 2.3.

D. Improper Bearing Installation - Not recommended for testing. There is no backward bearing installation.

Note: Do not understand the meaning of "ratchet action developed on cage."

E. Improper Coupling Installation - Not recommended for testing. If one hanger assembly is installed backward, it is impossible to attach the mating driveshafts. If all hangers are installed backwards the coupling at the transmission tail rotor quill will fail. The rigid coupling at the first hanger assembly does not allow sufficient misalignment between the transmission tail rotor quill and the first hanger assembly.

F. Improper Inner Coupling Installation - The Improper Installation procedures are outlined in Procedure BHC-II#1, described herein in Section E-2.3.

E-2.2.2. Short Shaft Tests

A. Loose V-Band - The Improper Installation procedures are outlined in BHC-II#3 and summarized in Section E-2.3.

B. Misalignment - Not recommended for test. The transmission moves relative to the engine during flight operations. On-board instrumentation to measure the misalignment would be required. Excessive misalignment causes short shaft coupling failures.

C. Improper V-Band Installation - The Improper Installation procedures are outlined in Procedure BHC-II#3, described herein in Section E-2.3.

E-2.2.3 Tail Rotor Shaft Tests

A. Out Of Balance - The Improper Installation procedures are outlined in Procedure BHC-II#4, described herein in Section E-2.3.

E-2.2.4. 42-degree Gearbox Tests

A. Loose Gearbox - The Improper Installation procedures are outlined in Procedure BHC-II #5, described herein in Section E-2.3.

E-2.3 Implant Part Inspection and Description Data Sheet Summary

The "Improper Installation Procedures" required to conduct the "Proposed Maintenance Installation Error Tests" submitted to AVSCOM per BHT Letter 81:JVH:peb-130, dated 16 June 1975, are summarized as follows:

E-2.3.1 BHC II#1 - Hanger Assembly P/N 204-040-600

Installation Notes/Recommended Operating Restrictions:

- TM-55-1520-210-20 for installation
- TM-55-1520-210-34 for assembly
- Operate helicopter per Profile #14 of the Airesearch Test Plan 73-9492 (Figure E-159).

Installation A - Remove attachment bolts and separate hanger assembly from mount. Install hanger assembly with 25 to 35 in-lb of bolt torque. Record bolt torque, hanger assembly S/N, and installation position on helicopter.

Installation B - Remove attachment bolts and separate hanger assembly from mount. Install hanger assembly snug to 10 in-lb of bolt torque. Record bolt torque, hanger assembly S/N, and installation position on the helicopter.

Installation C - Disassemble the hanger assembly. Install the AN4H30 retaining bolt with 25 to 35 in-lb of torque. Record bolt torque, hanger assembly S/N, and installation position on the helicopter.

Installation D - Disassemble the hanger assembly. Install the AN4H30 retaining bolt snug to 10 in-lb of torque. Record bolt torque, hanger assembly S/N, and installation position on the helicopter.

E-2.3.2 BHC-II#2 - Clamp Assy (TR Driveshaft) P/N 204-040-811

Installation Notes/Recommended Operating Restrictions:

- TM-55-1520-210-20 for installation
- Operate helicopter per Profile #14 of Airesearch Test Plan 73-9492.

Installation A - Remove one clamp assembly. Install clamp assembly bolts with 15 to 20 in-lb torque above nut friction. Record torque, driveshaft and clamp position.

Installation B - Remove one clamp assembly. Install clamp assembly bolts snug to 10 in-lb above nut friction. Record torque, driveshaft and clamp position.

Installation C - Orient clamps on one driveshaft at 0^{o} instead of 90^{o}. Record driveshaft tested.

Installation D - Install four bolts on one clamp assembly and on one driveshaft so that the bolt heads are trailing the direction of rotation. Record driveshaft tested and clamp position.

Installation E - Install two bolts (side by side) on one clamp assembly and on one driveshaft so that the bolt heads are trailing the direction of rotation. Record driveshaft tested and clamp position.

E-2.3.3 BHC-II #3 - Coupling Set (Short Shaft) P/N 204-040-716)

Installation Notes/Recommended Operating Restrictions:

- TM-55-1520-210-20 for installation
- Operate helicopter per Profile #16 of Airesearch Test Plan 73-9492 (Figure E-160).

Installation A - Remove coupling. Install coupling bolts with 40 to 60 in-lb of torque. Record driveshaft tested and clamp position.

Installation B - Remove coupling. Install coupling bolts snug to 10 in-lb torque. Record driveshaft tested and clamp position.

Installation C - Orient couplings at 0^{o} instead of 90^{o}. Record driveshaft tested.

Installation D - Install one bolt on one coupling so that the bolt head trails the direction of rotation. Record the drive-shaft tested and clamp position.

Installation E - Install both bolts on one coupling so that the bolt head trails the direction of rotation. Record the driveshaft tested and clamp position.

Installation F - Mismatch one coupling assembly with more than 1.50 grams difference between coupling halves. Record coupling half S/N's, delta weight of coupling halves, driveshaft tested, and coupling position.

E-2.3.4 BHC-II #4 - TR Driveshaft, P/N 204-040-620

Installation Notes/Recommended Operating Restrictions:

- Requires a driveshaft with an 0.8-inch-long (small) balance strip
- Identify the test driveshaft as an AIDAPS part with orange paint
- Operate helicopter per Profile #14 of Airesearch Test Plan 73-9492.

Note 3 of the driveshaft drawing requires that the static balance of the shaft be within 0.10 oz-in. Peeling one 0.8-inch-long balance strip introduces a change in balance of 0.144 oz-in. Peeling the name plate introduces a change in balance of 0.54 oz-in.

Installation A - Peel one 0.8-inch-long balance strip from one shaft. Record the weight of the strip in ounces. Strip weight times 1.5 = change in balance in oz-in. Record the shaft S/N and installed position.

Installation B - Peel the name plate from the same shaft used in Installation A. Record the weight of the name plate in ounces. Strip plus nameplate weight times 1.5 = change in balance in oz-in. Record the shaft S/N and installed position.

E-2.3.5 BHC-II #5 - 42-Degree Gearbox, P/N 204-040-003

Installation Notes/Recommended Operating Restrictions

- TM-55-1520-210-20 for installation
- Operate helicopter per Profile #14 of Airesearch Test Plan 73-9492.

Installation A - Remove mounting bolts and separate gearbox from mounts. Install gearbox with mounting bolts torqued 25 to 35 in-lb. Record the torque and gearbox S/N tested.

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Installation B - Remove mounting bolts and separate gearbox from mounts. Install gearbox with mounting bolts snug to 10 in-lb of torque. Record the torque and gearbox S/N tested.

E-2.4 Tiedown Testing

Improper installation maintenance error tests were conducted at the Fort Rucker tiedown facility with helicopter S/N 62-13360, (Bearcat #13) 29 July through 1 August 1975 as outlined in Table E-1.

14. This test profile is an abbreviated version of the "Maintenance Run for Tail Rotor Drive Train Implants," with the addition of a light on skids sequence. Collective pitch is flat for the tiedown portion of the test. Run each step for 3 minutes, recording during the last minute.

Step 1: Engine rpm - flight idle
Pedal input - neutral

Step 2: Engine rpm - 6400
Pedal input - full right

Step 3: Engine rpm - 6400
Pedal input - full left (i.e., to left pedal stop installed for tiedown)

Step 4: Engine rpm - 6600
Pedal input - full right

Step 5: Engine rpm - 6600
Pedal input - full left

Repeat steps 1 through 5 three times.

Step 6: After the special tiedown equipment has been removed from the aircraft, increase N_1 until the aircraft is light on skids. Keep N_1 constant for 3 minutes, recording during the last minute.

Step 7: Repeat step 6.

During each of the above recordings, the pilot should say, "This is profile number 14, run number ______, step number _____, N_1 is _______, N_2 is _________, and torque is ____________."

Figure E-159

Airesearch Test Profile No. 14

16. This is a ground run profile (not tied down) which will be used for vibration data collection. The maximum power level will be that which is required for light on skids (LOS) operation. N_2 = 6600 for the entire test. After each of the 5 N_1's listed is attained, hold N_1 steady for three minutes, recording during the last minute. Omit any steps which will exceed LOS operation.

Step 1

N_1 = 90%

Step 2

N_1 = 91%

Step 3

N_1 = 92%

Step 4

N_1 = 93%

Step 5

N_1 = 94%

During the one minute recording, the pilot should say, "This is profile number 16, step number ___; N_1 is ______, and torque is ________."

Figure E-160

Airesearch Test Profile No. 16

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TABLE E-1
MAINTENANCE INSTALLATION ERROR TESTS

Implant P/N	Description	Defect	Installation History	
			Date	Test Hours
BHC-II #1	#4 Hanger Assembly	Installation B @ 12 in-lb Torque	30 Jul 75	1.0
		Installation D @ 7 in-lb Torque	1 Aug 75	0.8
BHC-II #2	#4 Driveshaft Aft Clamp	Installation A @ 28 in-lb Torque	30 Jul 75	1.0
	#5 Driveshaft Aft Clamp	Installation A @ 35 in-lb Torque	30 Jul 75	0.9
BHC-II #3	Short Shaft Aft Coupling	Installation B @ 10 in-lb Torque	31 Jul 75	0.9
	Short Shaft Fwd Coupling	Installation B @ 10 in-lb Torque	31 Jul 75	1.0
BHC-II #4	Tail Rotor Driveshaft	————	No Tests Conducted	
BHC-II #5	42-Degree Gearbox	Installation A @ 35 in-lb Torque	29 Jul 75	0.9
		Installation B @ 17 in-lb Torque	29 Jul 75	0.8

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APPENDIX F
MAIC BEARING DEGRADATION PROGRAM
TEST CONDITION ANALYSIS AND RIG DESIGN

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FOREWORD

The bearing degradation subcontract issued by BHT required that a report be submitted upon completion of Task I (Engineering Evaluation) for BHT and Government approval, prior to initiation of testing. This appendix presents the report as received and approved, except for minor editorial clarifications which have been incorporated by BHT. Author of the report is Donald W. Moyer, Engineering Manager, MAIC Division of Pure Carbon Company.

F-1.0 INTRODUCTION

The Department of the Army is developing an Automatic Inspection, Diagnostic and Prognostic System (AIDAPS) for use on Army aircraft. AIDAPS is intended to achieve increased safety and reduced maintenance cost through automatic detection of incipient malfunctions. Data collection is currently being accomplished on UH-1H helicopter flight test vehicles at Fort Rucker, Alabama, by the AIDAPS prime contractor, Airesearch Manufacturing Company. Test cell data collection and technical support are being provided by Bell Helicopter Textron (BHT).

During Task I, the MAIC Division of Pure Carbon Company, Inc. (MAIC/PCC) conducted an engineering evaluation of eight different bearings. This was done to determine the best test procedures and test conditions at which to operate each bearing in order to fail that bearing in fatigue.

F-2.0 BEARING DATA

Based on the data contained in Table F-1 and the bearing drawings, MAIC/PCC calculated the load on the highest loaded bearing of a duplex or a triplex bearing set. The resultant L10 life and maximum Hertz stress were then calculated for all of the bearings. These data are summarized in Table F-II.

F-3.0 ANALYSIS

F-3.1 General Approach

All bearing analysis and bearing calculations were made using the book "Rolling Bearing Analysis" by Tedric A. Harris as a reference.

First a study was made as to what limits should be used for the various controllable variables that affect bearing fatigue life. Each bearing was then analyzed to determine what limits should be applied to each bearing.

F-3.2 Test Variables - Limiting Factors

To reduce the test time required to obtain classical fatigue failure of a given bearing, operating variables such as load, speed, oil temperature, oil viscosity, and oil flow rates can be controlled.

Increasing oil temperature decreases oil viscosity with consequent decrease in fluid film thickness. To avoid surface initiated fatigue, MAIC/PCC intends to use either MIL-L-7808 or MIL-L-23699 oil (to be supplied by BHT) at a supply temperature of 220° to 240°F, and at a flow rate sufficient to maintain the bearing outer race temperature at 275° to 325°F. The viscosity and quantity of oil should be sufficient to generate a full EHD film

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TABLE F-I

BHT-SUPPLIED BEARING OPERATING DATA

Bearing Number	Bearing Type/ Location	Dynamic Capacity*	RPM at 6600 Input	Applied Loading (lb)		Preferred Failure Mode
				Thrust	Radial	
204-040-143	Duplex Ball	5030				
Location 1	42° Input	5030	4303	430	761	Outer Race Spall
2	42° Output	5030	4303	108	517	
3	90° Input	5030		709	595	
4	Offset & Acc	5030	4145	0	732	
5	Sump Input	5030	4145	109	666	
6	T/R Output	5030	4303	533	737	
204-040-424	Duplex Ball 90° Output	3220	1657	231	67	Outer Race Spall
205-040-246	Triplex Ball Input	16500	6600	2270	1680	Outer Race Spall
205-040-245	Duplex Bearing XMSM Assembly	10925	3089	289	2470	Inner Race Spall
204-040-136	Ball	17270	324	5600	1188	Inner Race Spall
204-040-310	Roller	10900	4303		1512	Inner Race Spall
204-040-406	Roller	3320	4303		581	Inner Race Spall
204-040-407	Roller	7140	1657		1255	Inner Race Spall

*Specific Dynamic Capacity for Single Bearing in Duplex & Triplex Bearings.

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TABLE F-II

NORMAL OPERATING CONDITIONS - HEAVIEST LOADED BEARING

Bearing Number	Bearing Location	Load - (lb) Axial	Load - (lb) Radial	FA/FR	P (lb) (Note 1)	L10 (hr) (Note 2)	Maximum Hertz Stress-PSI (Note 3)	Bearing DN (Note 4)
143	1	430	380	1.129	382	8843	252,000	150,600
143	2	108	259	.417	259	28371	218,000	150,600
143	3	709	298	2.379	511	3694	250,000	150,600
143	4	100	366	.273	366	10437	244,000	145,100
143	5	109	333	.327	333	13858	237,000	145,000
143	6	533	369	1.444	437	5907	249,000	150,600
424		231	34	6.794	189	49740	195,000	66,300
246		1135	560	2.027	1217	1557	206,000	528,000
245		289	1235	0.234	1235	893	228,000	370,700
136		5600	1188	4.714	4719	3969	280,000	35,600
310		0	1512	N/A	1512	2785	208,000	172,100
406		0	581	N/A	581	1285	207,000	107,600
407		0	1255	N/A	1255	3287	216,000	82,800

Note 1: P = equivalent radial load

Note 2: L10 = calculated time to first indication of failure of 10 percent of the bearing population.

Note 3: Compressive stress in inner race material.

Note 4: DN = bearing bore (milimeters) x operating speed (RPM)

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in the bearings at their operating speeds and loads.

The variation of load and speed affects ball and roller bearings differently. The effect of these variables on each type of bearing is discussed below.

F-3.2.1 Ball Bearings

F-3.2.1.1 Load Limiting Factors

The amount by which the load can be increased is limited by the Hertz stress at which plastic deformation begins to take place, generally accepted as 400,000 psi to 500,000 psi in completed rolling element bearings. Although certain bench tests are sometimes run at higher stress levels, full scale bearing tests are not normally conducted at stress levels over 400,000 psi.

F-3.2.1.2 Speed Limiting Factors

Rotational speed is limited either by the amount of heat that can be dissipated by the lubrication system so as to prevent thermal lockup of the bearing, or by the ball running over the inner race shoulder in thrust-loaded bearings.

F-3.2.1.3 Test Program Factors

In this program we are attempting to fail each bearing in its normal running track on a particular race. Therefore we must adjust the thrust and radial loads and shaft speed so as to maintain the normal operating contact angle on the race being degraded.

Since speed and load have different effects on the inner and outer races, it is not possible to maintain the normal operating contact angle on both.

F-3.2.2 Roller Bearings

F-3.2.2.1 Load Limiting Factors

The load applied to a cylindrical roller bearing, in addition to being limited to a maximum Hertz stress of 400,000 psi, is limited by edge loading of the rollers. This edge loading can be caused by using a straight roller with no crown or by large undercuts near the flange of the raceway. Should fatigue failure occur at the ends of the rollers rather than the center of the roller track, the radial load should be reduced.

F-3.2.2.2 Speed Limiting Factors

Rotational speed does not affect the location of the high stress area on cylindrical roller bearings. Therefore, the limiting

speed is determined by the ability of the bearing to reach a stabilized operating temperature.

F-3.3 Test Conditions - Selection

F-3.3.1 Ball Bearings

Figure F-1 shows the general relationship between shaft speed, thrust load and contact angle for angular contact type ball bearings. This figure will be used as a guide in determining the loads and speeds at which to run the following bearings.

F-3.3.1.1 Ball Bearing P/N 204-040-143

This bearing is used in six different locations in the UH-1H drive train. In each location, the bearing is subjected to a different combination of axial and radial loads, (Tables F-I and F-II). The preferred failure mode for this bearing is outer race fatigue spalling. Therefore, the test loads will be set so as to maintain the normal operating outer race contact angle.

These bearings are divided into three groups, each group consisting of bearings whose operating conditions are similar. The test conditions for each group are as follows:

Group I consists of bearings used in locations 2, 4, and 5 (Table F-I). These bearings all carry a much higher radial load (FR) than axial load (FA) and have been analyzed as radially loaded bearings to calculate the Hertz stress. Since increasing shaft speed and radial load both tend to decrease the outer race contact angle, the FA/FR has been increased by 50%. The higher value of axial thrust will tend to increase the contact angle of the outer race, thus counteracting the increased radial load and increased speed.

The radial load will be increased to a value that will cause the bearing to operate at a maximum Hertz stress of 400,000 psi on the inner race. The shaft speed will be increased to obtain a value of 400,000 DN (bore, mm x RPM). This will result in the inner race contact angle increasing by an estimated 2 degrees over the normal operating contact angle.

Group II consists of the bearings used in locations 1 and 6 (Table F-I). These bearings carry an axial load slightly higher than their radial load and will be analyzed as combined loaded bearings to determine Hertz stress. Since the radial load is a smaller part of the overall load than for Group I, the average value of FA/FR will be increased only 25%, from 1.284 to 1.605.

The thrust and radial loads will be increased to obtain a Hertz stress of 400,000 psi on the inner race and the shaft speed

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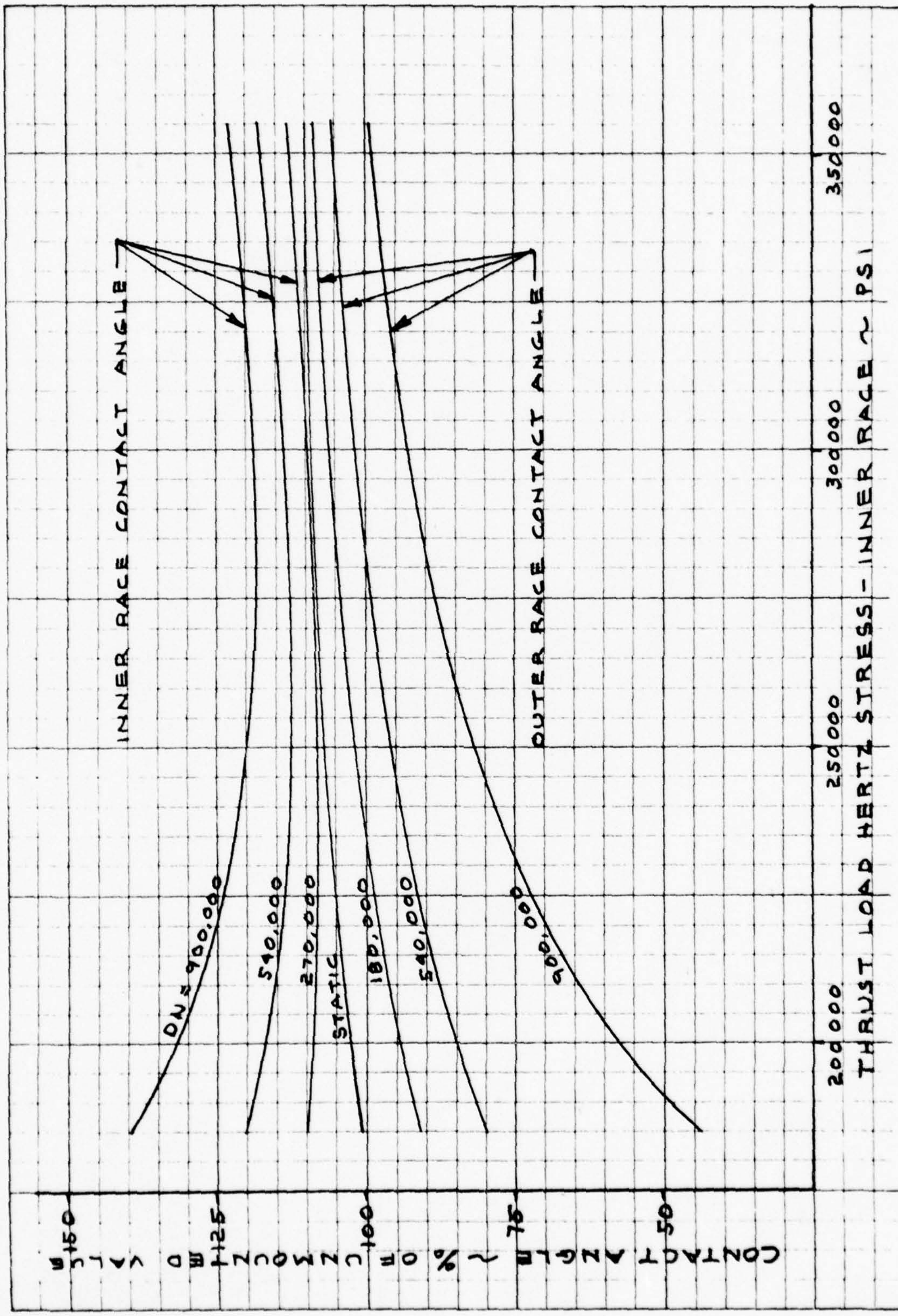

Figure F-1. Relationship between contact angle, load, and speed.

increased to 400,000 DN. This will again cause the inner race contact angle to run an estimated 2 degrees higher than normal.

Group III consists of the bearings used in location 3 (Table F-I). The bearing in this location is carrying a much higher thrust load than radial load, and therefore the FA/FR was not changed. The thrust and radial loads will be increased to obtain a Hertz stress of 400,000 psi, and the shaft speed increased to 400,000 DN.

F-3.3.1.2 Ball Bearing P/N 204-040-424

The preferred failure mode of this bearing is outer race fatigue. This bearing is subject to a very high thrust load in relation to its radial load. Therefore, the FA/FR was not changed. The radial and axial loads were both increased to obtain a maximum Hertz stress of 400,000 psi. The shaft speed was increased to 400,000 DN. At these test conditions, the inner race contact angle is about 2 degrees higher than normal.

F-3.3.1.3 Ball Bearing P/N 205-040-246

The preferred mode of failure for this bearing is also outer race fatigue. Because of the low Hertz stress and moderate speed at which this bearing operates, it is not possible to increase the speed enough to reduce the outer race contact angle, which is increased by increasing thrust load, to its normal value without exceeding a million DN. To compensate for this, the FA/FR will be reduced by 25% and the shaft speed will be increased by 50%. The axial and radial loads will be increased to obtain a Hertz stress of 400,000 psi.

F-3.3.1.4 Ball Bearing 205-040-245

The preferred failure mode for this bearing is inner race fatigue. Because of the high radial load compared to the axial load, this bearing will be analyzed as a radially loaded bearing. The FA/FR value will not be changed as the small increase in both axial load and a 50% increase in shaft speed should compensate for the decreased contact angle caused by the large increase in radial load.

F-3.3.1.5 Ball Bearing 204-040-136

The preferred mode of failure is inner race fatigue. This bearing has a high thrust load compared to its radial load. Since increasing thrust and speed both cause the inner race contact angle to increase, the value of FA/FR was decreased by 25%. The thrust and radial loads were then calculated for a maximum Hertz stress of 400,000 psi, and the shaft speed increased to 400,000 DN.

F-3.3.2 Roller Bearings

The preferred mode of failure of the three roller bearings is inner race fatigue. The radial load was increased to obtain a maximum Hertz stress of 400,000 psi and the shaft speed was increased to give a resultant bearing DN of 400,000 except for bearing part No. 204-040-406, whose bore is only 25 mm. For this bearing the shaft speed was increased to 13,000 rpm (maximum test stand speed), resulting in a DN of 325,000.

It is noted that bearing drawings for bearing part Nos. 204-040-406 and -407 do not specify the amount of roller crown. If these are straight rollers or only slightly crowned the load will be reduced to give a maximum Hertz stress of 250,000 to 300,000 psi.

F-3.4 Proposed Test Conditions

Table F-III summarizes the proposed test conditions for each bearing and the estimated test time required to fail the number of bearings required by BHT.

4.0 TEST RIG DESIGN (MAIC TASK II)

MAIC/PCC is designing three test rigs in order to complete testing within the time requested by BHT.

A design feature of all three rigs will be the inclusion of loading bolts or cutaway bearing housings for all bearings with a preferred failure mode of outer race fatigue. The loading bolts or cutaway housing will cause a local deflection of the outer race, causing it to fail prior to the inner race.

F-4.1 Test Rig No. 1 (Figure F-2)

Figure F-2 shows the rig which will be used to test both small ball bearings, P/N 204-040-143 and -424, in the front position and roller bearing P/N 204-040-310 in the middle position. When the ball bearings are operating at their proposed test loads, the roller bearing will be operating at a lower Hertz stress than proposed; but any failures generated during this phase should be usable in the program.

F-4.2 Test Rig No. 2

Rig No. 2 is shown by Figure F-3. This rig is identical to rig No. 1, except that the front bearing position will be used to test the two small roller bearings P/N 204-040-406 and -407.

F-4.3 Test Rig No. 3 (Figure F-4)

This rig (Figure F-4) will be used to test the three large ball bearings, P/N 204-040-136, 205-040-245 and 205-040-246.

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TABLE F-III

PROPOSED TEST CONDITIONS

Bearing Number	Location	Load-Lbs. Axial	Load-Lbs. Radial	FA/FR	Speed rpm	DN $\times 10^{-6}$	Maximum Hertz Stress psi $\times 10^{-3}$	L10 Hrs.	No. Failures Needed	Estimated Total Test Hours (3)
143	2,4,5	894	1803	.496	11429	.40	400 (1)	31.7	9	2850
	1,6	2305	1436	1.605	11429	.40	400 (1)	30.2	4	1200
	3	2868	1205	2.380	11429	.40	400 (1)	21.0	2	210
424		2472	363	6.810	10000	.40	400	6.8	3	240
246		7569	4979	1.520	9100	.79	400	11.8	3	360
245		1497	6396	.234	4634	.56	400	17.9	3	540
136		12800	3620	3.536	3636	.40	400	17.0	0	0
310(MRC)			5915		10000	.40	400	12.8	12	1540
310(MRC)(4)			3186		13000	.52		77.3		
310(MRC)(5)			2704		11429	.46		152.0		
406(MRC)			2124		13000	.32	400 (2)	16.1	3	480
407(MRC)(6)			3944		10000	.50		13.1	3	390

1) May have to be increased to 450,000 psi to reduce test time to acceptable level.
2) May be too high if not properly crowned.
3) Based on running twice as many bearings as no. of failures required to approx. 5 x L10 life (approx. L50).
4) When using 310 MRC bearing as slave bearing for 407 MRC bearing test.
5) When using 310 MRC bearing as slave bearing for 143 bearing test location 2, 4 & 5.
6) Tested concurrently with 310 MRC bearing at rated test conditions.

Total Test Time Rig No. 1	4500 Hours	36 Weeks
Total Test Time Rig No. 2	2020 Hours	16 1/2 Weeks
Total Test Time Rig No. 3	900 Hours	9 Weeks

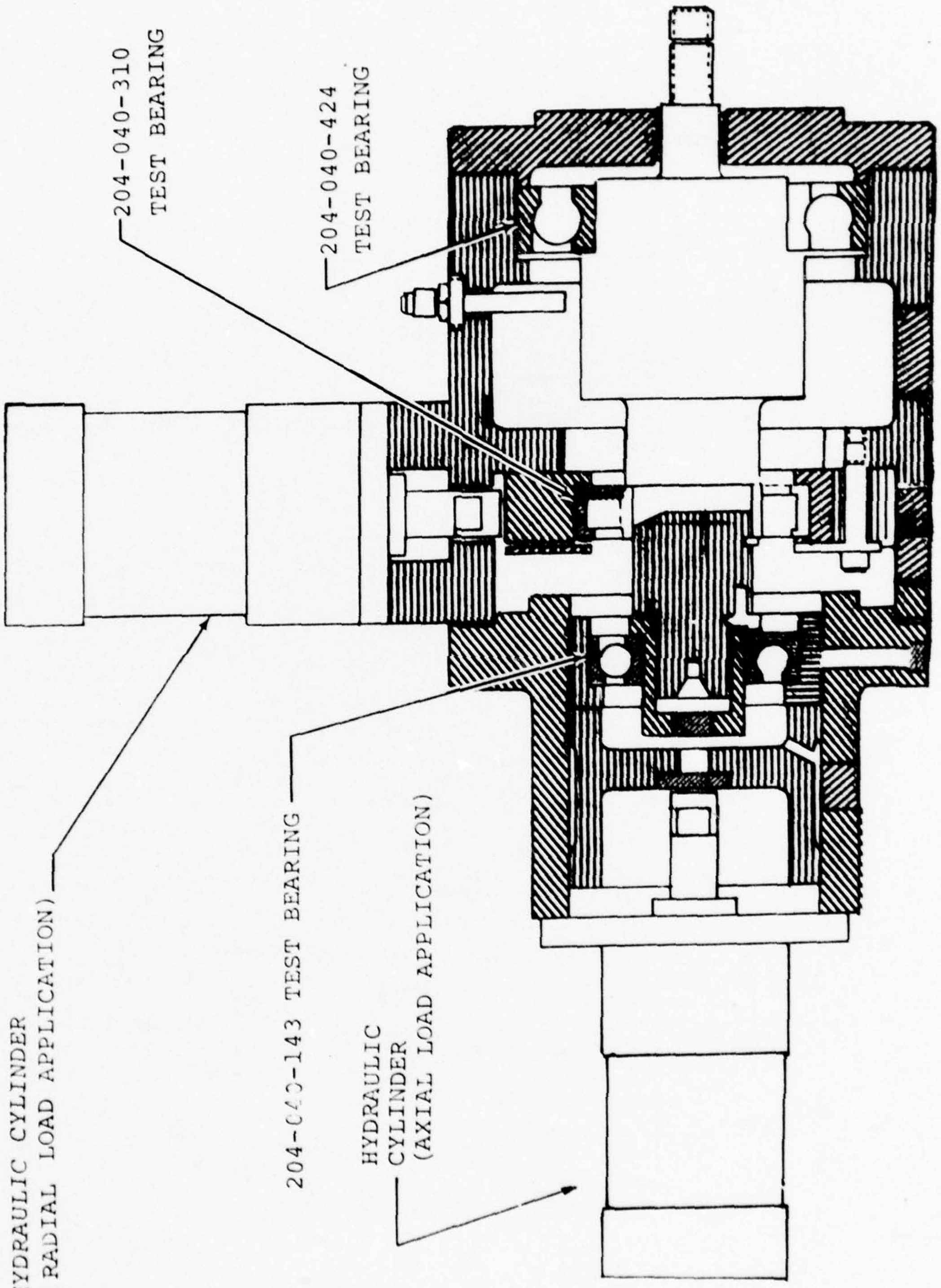

Figure F-2. MAIC test rig No. 1.

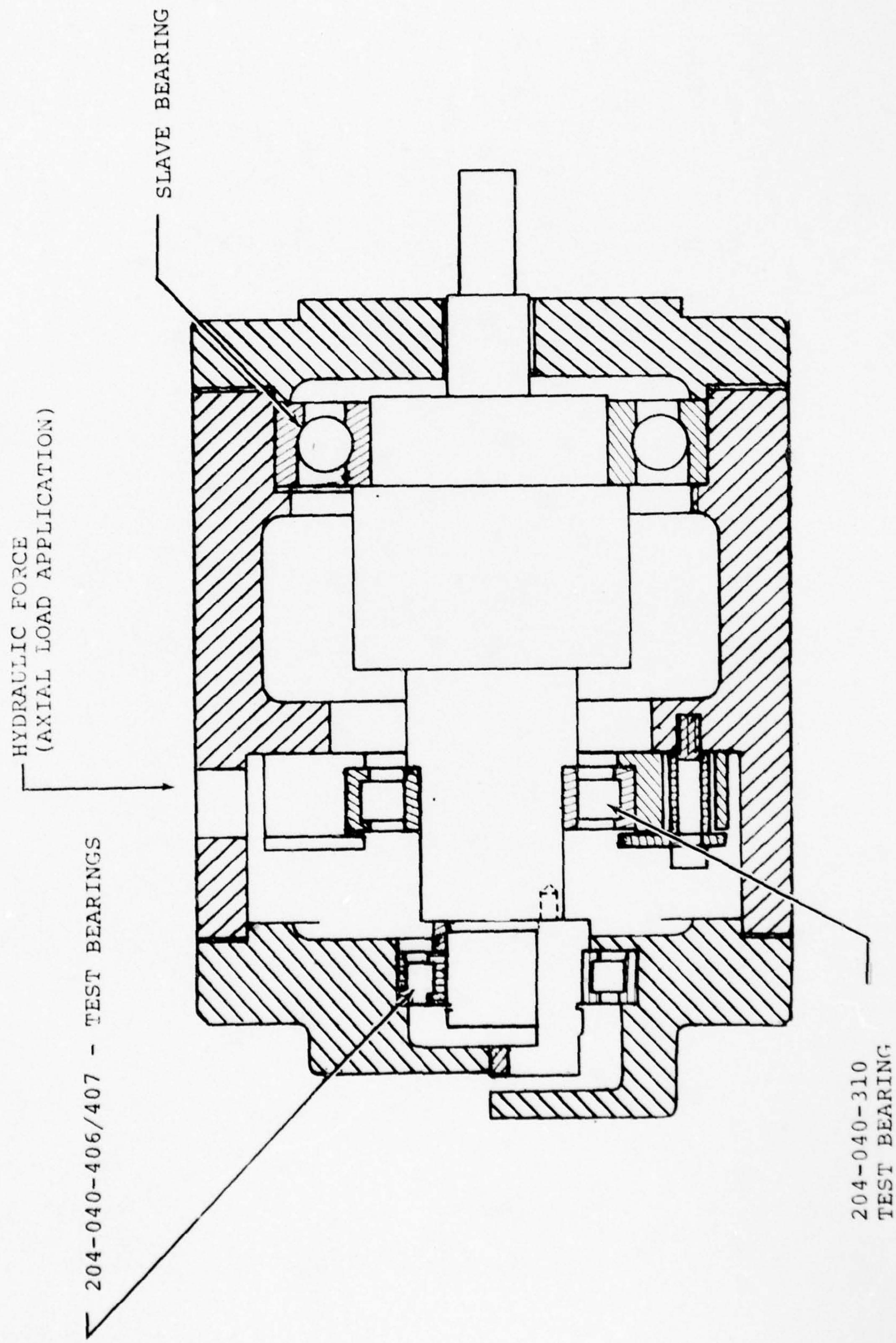

Figure F-3. MAIC test rig No. 2

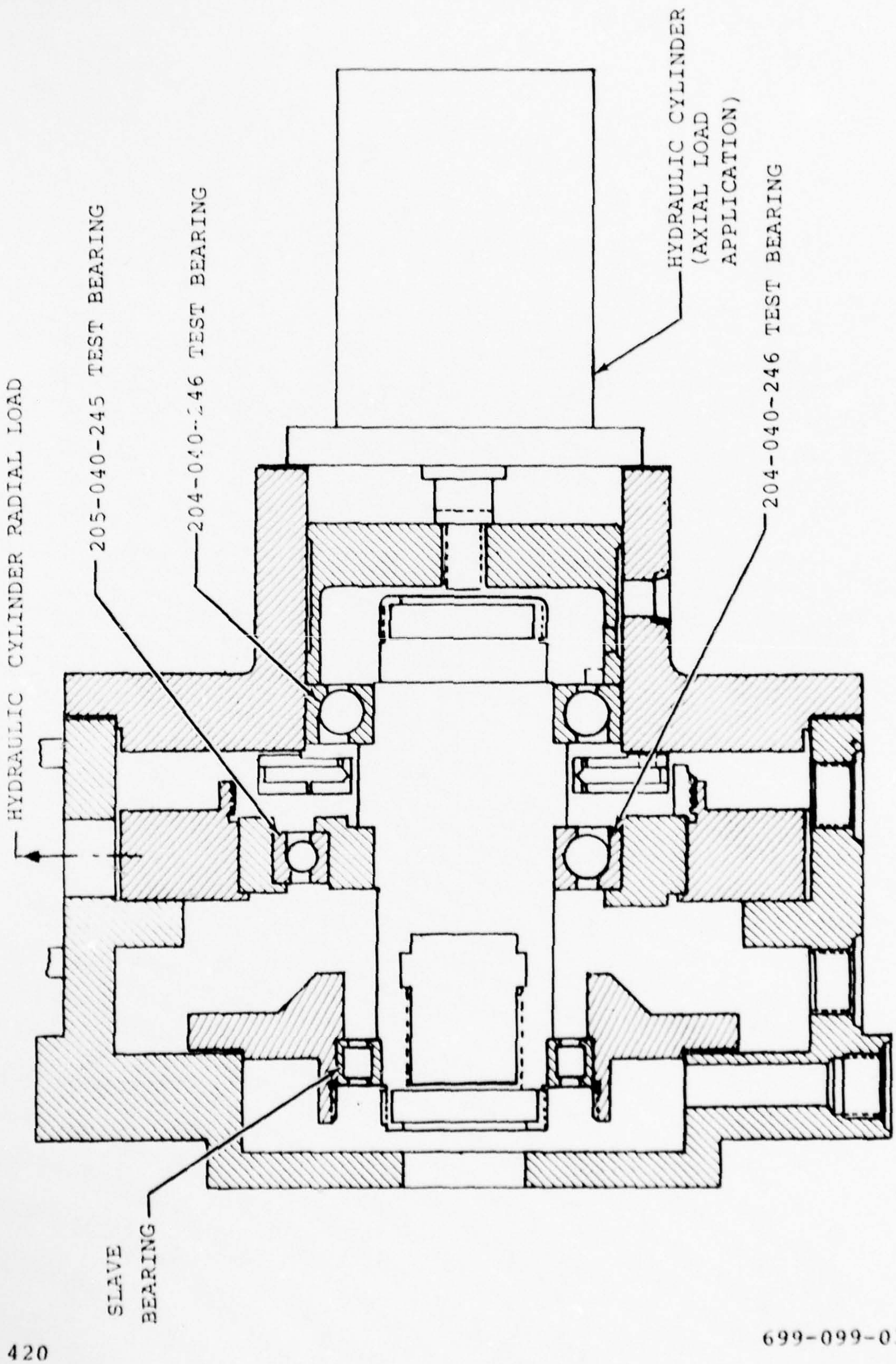

Figure F-4. MAIC test rig No. 3

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APPENDIX G
ENGINEERING AND TECHNICAL SUPPORT

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G-1.0 UH-1H TIEDOWN EQUIPMENT AND PROCEDURES

G-1.1 Introduction

The UH-1H AIDAPS helicopters were operated on a tiedown pad at Fort Rucker for drive train green runs, maintenance runs, and certain data collection runs. BHT provided tiedown equipment, special tool and modification designs, and recommended operational procedures as described herein.

G-1.2 General Operational Procedures

Tiedown operation is outside the normal helicopter operational environment. Therefore, the following suggestions were made by BHT to supplement the normal operating procedures.

a. The power requirement for a tail rotor design is determined for transient flight maneuvers. Full left pedal displacement demands over 220 horsepower, whereas maximum gross weight steady state hovering tail rotor power is just under 100 horsepower. The cooling airflow provided to the 42- and 90-degree gearboxes is less during tiedown operation than during flight. With large left pedal inputs, the gearbox oil temperature limit may be exceeded, resulting in premature gear and/or bearing failures. A 1/2 travel (from neutral pedal) left pedal restraint is therefore suggested to limit the tail rotor system to a maximum of 100 horsepower.

b. One-inch-thick, high durometer rubber pads under the skid gear are recommended to prevent excessive skid gear wear due to skid scuffing.

c. The helicopter should be ballasted to near maximum gross weight, if possible, to help stabilize the aircraft, rigidize the skid gear, and reduce the amount of tension required through the tiedown.

d. Operations in gusty wind conditions should be avoided because of the probable inability to obtain stabilized test conditions. To prevent undesirable high blade flapping motion, it would be advisable to tie down the helicopter with the nose into the prevailing wind. Wind component should not exceed 20 knots headwind, 10 knots sidewind, or 10 knots rearwind.

e. The ground area within a radius of approximately 100 feet of the tiedown point should be relatively flat and unobstructed to permit free flow outward of the rotor downwash.

f. The area around the tiedown rig should be checked before each run for loose objects which might be picked up by the rotor downwash and recirculated into the rotor.

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G-1.3 Tiedown Equipment

Tiedown equipment requirements had been previously established for the USAF, and described in BHC Drawing 212-038-029, as follows.

G-1.3.1 204-900-001 WHT-1 Tiedown Tool. This tool is a large turnbuckle device that picks up a single point on the lift link beam and a single ground hard point directly beneath the lift link beam and helicopter. The tool is designed for a working tension load of 14,000 lbs and is static tested to 35,000 lbs.

G-1.3.2 212-HES-295 Tiedown Fitting. This fitting bolts to the tail skid attachment fitting after removal of the tail skid. Two tiedown cables (left and right) perpendicular to the longitudinal axis and nearly perpendicular to the vertical axis counteract the main rotor torque and tail rotor thrust to prevent the helicopter from turning.

G-1.3.3 212-HES-290 Cyclic Stick Tool. During the tiedown tests, large cyclic inputs can create excessive misalignment between the transmission and engine due to airframe bending, which does not occur during flight. Excessive misalignment can cause premature transmission input quill failure. The cyclic tool clamps to the bottom of the cyclic stick. It prepositions the cyclic controls near the optimum location for rotor operation and restricts skid motion to prevent high blade flapping and airframe pitch and lateral motion against the tiedown restraints.

G-1.3.4 Skid Gear "U" Bolt Restraints. The restraints increase the gear spring rate and rigidize the helicopter airframe support to prevent undesired airframe pitch and lateral motions during control inputs. In lieu of "U" bolts, a cross tie arrangement between the skids is as effective in restraining the skid gear. The gear is restrained before the WHT-1 tiedown fitting is installed.

G-1.3.5 Jack Point Restraints. The tiedown restraints at the forward and aft jack points are per a special USAF request. They are not used for most tiedown procedures.

G-1.3.6 UH-1H Left Pedal Stop Fabrication and Installation. As noted in Sect. G-1.2a, left pedal inputs should be limited during tiedown operation to approximately 1/2 travel. Figure G-1 shows the design of a stop for this purpose. Installation of the stop is as follows:

a. Attach a portable hydraulic test unit and apply hydraulic power per Chapter 6 of TM55-1520-210-20.

b. Cycle pedals full right and left and hold full left pedal.

c. Turn tail rotor to horizontal position.

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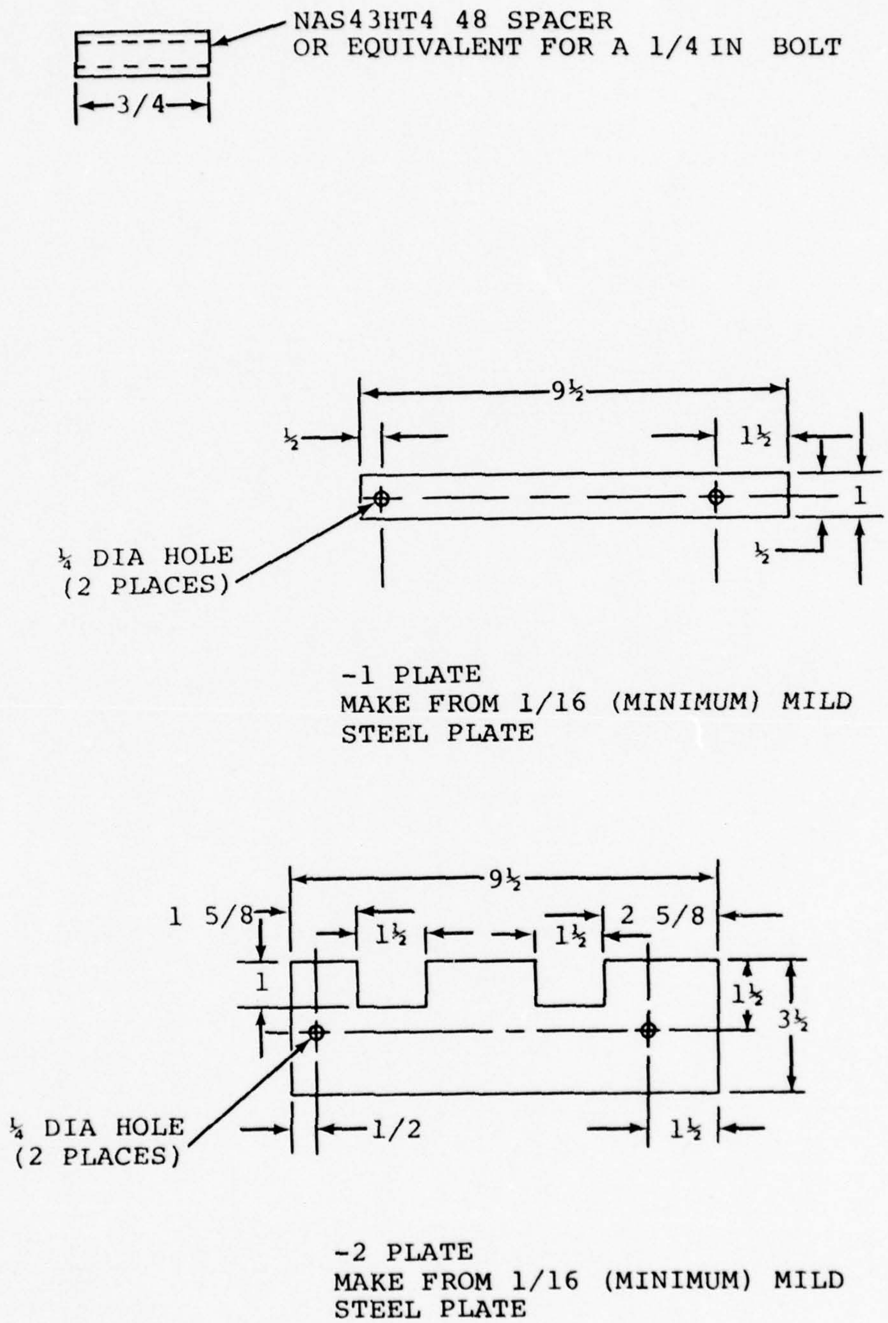

Figure G-1. UH-1H AIDAPS tiedown left pedal stop.

d. Set a propeller blade protractor to zero index. Place protractor on flat surface of tail rotor blade just outboard of grip.

NOTE: During this series of measurements maintain the same orientation of protractor. That is, the spirit level must be on the forward side for all readings, or on the aft side for all readings.

e. Flap rotor in one direction against static stop. Measure and record protractor reading. Flap blade in opposite direction to stop and record reading.

f. Both readings should be 19 degrees $\pm$ 1 degree.

g. Apply right pedal and install the tiedown pedal stop per Figure G-2 on the right heel rest (copilot's side is preferable).

h. Apply left pedal until the blade protractor reads 11-1/2 degrees. Hold 11-1/2 degrees and move the pedal adjust knob until the right pedal contacts the pedal stop.

i. Flap rotor in one direction against static stop. Measure and record protractor reading. Flap blade in opposite direction to stop and record reading.

j. Place protractor with same orientation on opposite blade. Repeat Step i.

k. Add the four recorded protractor readings. Divide by four. The average blade pitch angle should be 11-1/2 degrees $\pm$ 1/2 degree.

l. If blade readings are not satisfactory, move the pedal adjust against the stop and repeat steps i, j, k until the protractor readings are within limits.

m. Remove the pedal adjust stop or block the handle so the adjustment will not engage.

G-1.4 Tiedown Green Run Procedures

G-1.4.1 Introduction. Procedures were developed by BHT in order that green runs of drive train components could be conducted at Fort Rucker, using a tied-down helicopter in lieu of a test stand. These procedures apply to the AIDAPS program only.

1.4.2 Transmission Green Run. The recommended procedure for tiedown green run of AIDAPS UH-1H transmissions is as follows:

a. Install the Hamilton Standard 42-degree gearbox and 90-degree gearbox chromel-alumel thermocouple in the sight

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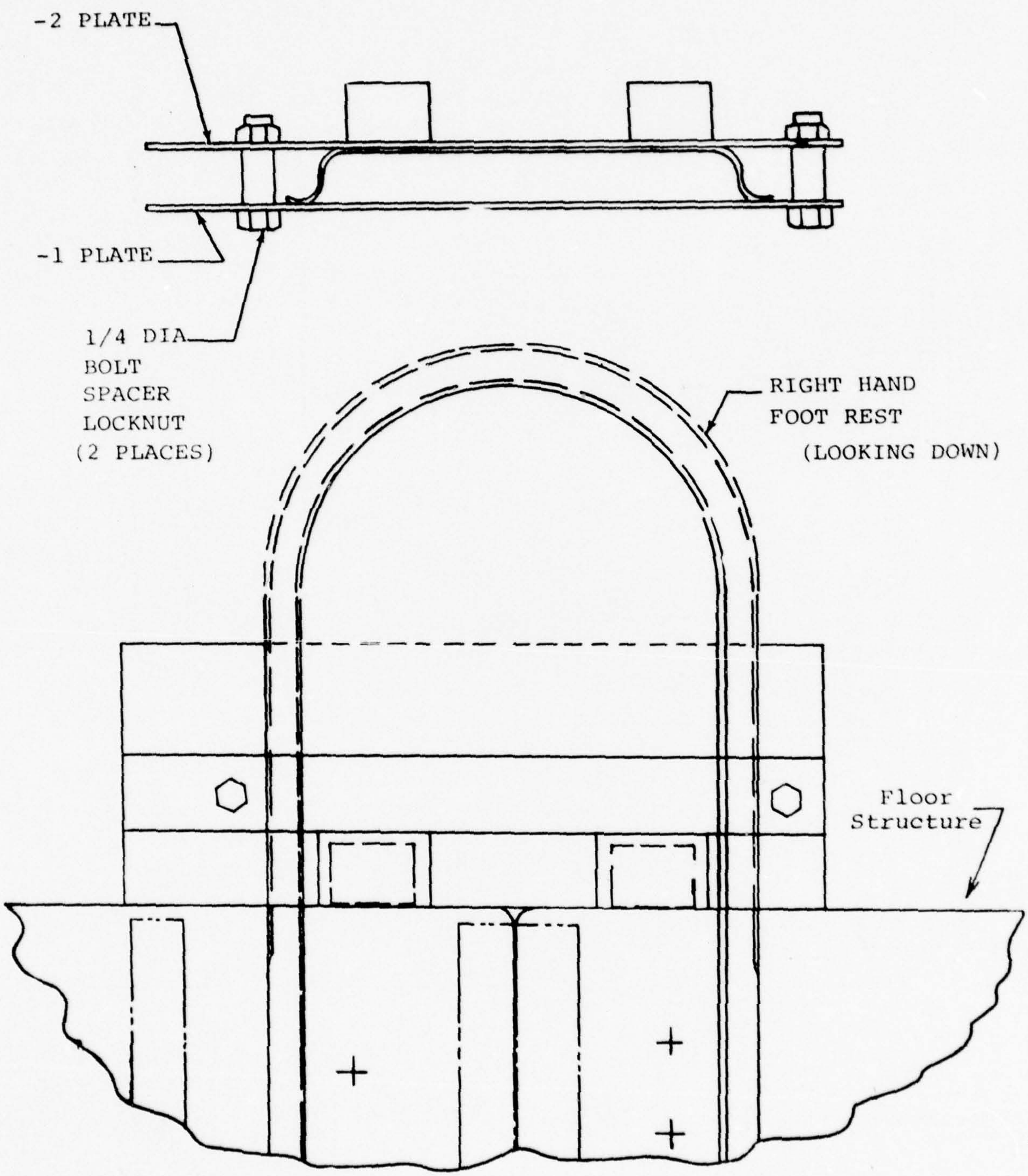

Figure G-2. UH-1H left pedal stop for tiedown operation.

glass window (this thermocouple was installed in the sight glass window in the two helicopters received from the Granite City/Parks College testing) per the Hamilton Standard Drawings SK 79730-110 and SK 79730-140. Remove the TC #2 thermocouples and monitor the TC #1 thermocouples with an appropriate chromel-alumel temperature indicator.

b. Perform Lubrication Check Run per Section G-1.6.2

c. Install the following helicopter components to perform a test run of the transmission: transmission, mast controls, stabilizer bar assembly, main rotor hub and blade assembly, all driveshafts, gearboxes, and tail rotor hub and blade assembly.

d. Do not install the engine cowling or transmission cowling.

e. Verify that the helicopter has been lubricated and serviced. Visually inspect the following:

All tiedown points for security
Oil system for security and leakage
Fuel system for security and leakage
Hydraulic system for security and leakage
Flight controls for security and leakage
Engine accessories and controls for security, loose connections, and proper operation.

NOTE: Throughout the whole testing procedure, all components should be carefully checked for evidence of leakage and abnormal noise.

f. Start engine and bring to flight idle. Verify that all operating parameters are within limits. Perform Steps 1 through 5 of the green run cycle, Table G-I.

NOTE: At no time allow the gearbox oil temperature to exceed 212°F (100°C).

g. Stop the engine and perform the following inspections:

  a. Remove transmission jets and visually inspect for foreign materials, burrs and damaged jets. Clean and reinstall.

  b. Remove airmaze filter. Visually inspect for foreign material. Clean in solvent (Item 1, Table 3-15 of DMWR 55-1615-156) and reinstall.

  c. Check the magnetic chip detector for foreign material or chips. Clean and reinstall.

h. Start the engine and bring to flight idle. Verify that

TABLE G-I

UH-1H UNIVERSAL TRANSMISSION

GREEN RUN TEST CYCLE

AIDAPS TIEDOWN ONLY

Step	Time-(hr)		Engine Input			Tail Rotor			Notes and Remarks
	Interval	Accum	RPM	Torque PSI	Approx HP	RPM	Pedal Input	Approx HP	
1	0.1	0.1	Flight Idle - Flat Pitch		-	----	Neutral	----	△1 Full left pedal is defined as full deflection to the 1/2 left pedal travel test stop as set up in the Tiedown Instructions.
2	0.1	0.2	4400	Approx 8-12	130	2900	Full Left	26	
3	0.1	0.3	4800	↓	141	3193	△1 ↓	35	
△2 4	0.1	0.4	5200	↓	153	3468	↓	44	
5	0.1	0.5	5800	↓	171	3779	Full Right	34	
STOP ENGINE FOR INSPECTION									
6	0.1	0.6	6400	20	440	4170	Full Right	46	△2 Record the 90-degree gearbox and the 42-degree gearbox oil temperatures. The gearbox temperature is to be monitored continuously. Either gearbox temperature is not to exceed 212°F (100°C).
7	0.1	0.7	6600	34	775	4300	↓	50	
8	0.1	0.8	6400	38	840	4170	↓	46	
△2 9	0.1	0.9	6400	45	990	4170	Full Left	87	
10	0.1	1.0	6400	△3 49	1077	4170	Full Right	46	
11	Rapidly decrease collective and roll off power. Check for dual tach needle split. Allow rotor to coast down at flat pitch.								
STOP ENGINE FOR INSPECTION									

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TABLE G-1 (Continued)

Step	Time-(hr)		Engine Input			Tail Rotor			Notes and Remarks
	Interval	Accum	RPM	Torque PSI	Approx HP	RPM	Pedal Input	Approx HP	
12	0.2	1.2	6600	40	900	4300	Full Left	90	△3 Hot day conditions may require more power than the engine is capable of producing. Do not exceed the power limits outlined in TM 55-1520-210-10.
13	0.1	1.3		△3 50	1144		Neutral	30	
14	0.2	1.5		40	900		Full Left	90	
15	0.1	1.6		50	1144		Neutral	30	
△2 16	0.2	1.8		40	900		Full Left	90	
17	0.1	1.9		50	1144		Neutral	30	
18	Rapidly decrease collective and roll off power. Check for dual tach needle split. Allow rotor to coast down at flat pitch.								

STOP ENGINE FOR INSPECTION

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all operating parameters are within limits. Perform Steps 6 through 11 of the green run cycle, Table G-I.

i. Stop the engine and repeat Step g inspection.

j. Start the engine and bring to flight idle. Verify that all operating parameters are within limits. Perform Steps 12 through 18 of the green run cycle, Table G-1.

k. Repeat inspection (Step g).

l. The green run is now complete, and the transmission is ready for inspection qualification per DMWR 55-1615-156.

1.4.3 Transmission Accessory Quill Green Run. The recommended procedure for ground green run of AIDAPS UH-1H transmission accessory drive (hydraulic pump and generator) quills is as follows:

a. Install the test quill in the transmission and perform the backlash check as outlined in DMWR 55-1615-155.

b. Prepare the helicopter for ground run. The tiedown facility is not required. Do not install the engine or transmission cowling.

c. Start the engine and bring to flight idle. Verify that all operating parameters are within limits. Perform the following run cycle. Maintain neutral pedals and full-down collective during run.

Step	Time Interval	Hours Accum.	Engine RPM
1	0.1	0.1	Flight Idle
2	0.2	0.3	4800
3	0.2	0.5	5800
4	0.2	0.7	6400
5	0.2	0.9	6600

d. The green run is now complete and the test quill is ready for inspection qualification per DMWR 55-1615-156.

e. Perform the following inspection on the universal transmission:

Remove the airmaze filter. Visually inspect for foreign material. Clean in solvent (Item 1, Table 3-15 of DMWR 55-1615-156) and reinstall.

Check the magnetic chip detector for foreign material or chips. Clean and reinstall.

G-1.4.4 42-Degree and 90-Degree Gearbox Green Run. The recommended procedure for tiedown green run of AIDAPS UH-1H 42-degree and 90-degree gearboxes is as follows:

a. Install the Hamilton Standard 42-degree gearbox and 90-degree gearbox chromel-alumel thermocouple in the sight glass window (these thermocouples were installed in the sight glass windows in the two helicopters received from Granite City/Parks College testing) per the Hamilton Standard Drawings SK 79730-110 and SK 79730-140. Remove the TC #2 thermocouples and monitor the TC #1 thermocouples with an appropriate chromel-alumel temperature indicator.

b. Before the 42-degree gearbox green run, perform lubrication check run (Per G-1.6.3).

c. Install the following helicopter components to perform a test run of the 42-degree and/or 90-degree gearbox: transmission, mast controls, stabilizer bar assembly, main rotor hub and blade assembly, all drive shafts, gearboxes, and tail rotor hub and blade assembly.

d. Do not install the gearbox fairings.

e. Verify that the helicopter has been lubricated and serviced. Visually inspect the following:

   a. All tiedown points for security
   b. Oil system for security and leakage
   c. Fuel system for security and leakage
   d. Hydraulic system for security and leakage
   e. Flight controls for security and leakage
   f. Engine accessories and controls for security, loose connections and proper operation

   NOTE: Throughout the whole testing procedure, all components should be carefully checked for evidence of leakage and abnormal noise.

f. Start engine and bring to flight idle. Verify that all operating parameters are within limits. Perform Steps 1 through 5 of the green run cycle, Table G-II.

   NOTE: At no time allow the gearbox oil temperature to exceed 212^{O}F (100^{O}C).

g. Stop the engine and check the gearbox magnetic chip detector for foreign material or chips. Clean the magnetic chip detector and reinstall.

h. Start the engine and bring to flight idle. Verify that all operating parameters are within limits. Perform Steps 6

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TABLE G-II
UH-1H 42-DEGREE AND 90-DEGREE GEARBOX
GREEN RUN TEST CYCLE
AIDAPS TIEDOWN ONLY

Step	Time-Hrs		Engine RPM	Coll Pitch	Tail Rotor		
	Interval	Accum			RPM	Pedal Input	Approx HP
1	0.1	0.1	Flight Idle	Flat	-	Neutral	-
2	0.1	0.2	4400	↓	2900	Full Left	26
3	0.1	0.3	4800	↓	3193	△1 ↓	35
△2 4	0.1	0.4	5200	↓	3468	↓	44
5	0.1	0.5	5800	↓	3779	Full Right	34
STOP ENGINE FOR INSPECTION							
6	0.1	0.6	6400	Flat	4170	Full Right	46
7	0.1	0.7	6600	↓	4300	↓	50
8	0.1	0.8	6400	↓	4170	↓	46
△2 9	0.1	0.9	6400	↓	↓	Full Left	87
10	0.1	1.0	6400	↓	↓	Full Right	46
STOP ENGINE FOR INSPECTION							
11	0.2	1.2	6600	Flat	4300	Full Left	90
12	0.1	1.3	↓	↓	↓	Neutral	30
13	0.2	1.5	↓	↓	↓	Full Left	90
14	0.1	1.6	↓	↓	↓	Neutral	30
△2 15	0.2	1.8	↓	↓	↓	Full Left	90
16	0.1	1.9	↓	↓	↓	Neutral	30

Notes and Remarks

△1 Full left pedal is defined as full deflection to the 1/2 left pedal travel test stop as set up in the Tiedown Instructions.

△2 Record the 42-degree and 90-degree gearbox temperatures. The gearbox temperature is to be monitored continuously. Either gearbox temperature is not to exceed $212^{o}F(100^{o}C)$.

through 10 of the green run cycle, Table G-II.

i. Stop the engine and repeat inspection (Step g).

j. Start the engine and bring to flight idle. Verify that all operating parameters are within limits. Perform Steps 11 through 16 of the green run cycle, Table G-II.

k. The green run is now complete. The 42-degree and/or 90-degree gearbox is ready for inspection qualification per DMWR 55-1560-123 and/or DMWR 55-1560-127.

G-1.5 Tiedown Maintenance Run Procedures

G-1.5.1 Introduction. The procedures described in this section were developed by BHT for use at Fort Rucker. Maintenance runs were performed prior to flight release of AIDAPS helicopters with defective parts implanted. This procedure was to insure that the component containing the defective implant had been properly reassembled and installed, and that the deterioration rate of the implanted part was acceptably low.

G-1.5.2 Transmission Maintenance Run; Main Rotor Drive Implants The following procedure is recommended for maintenance check of an implant in the transmission input quill, input bevel gear, planetary assemblies, and upper mast bearing.

a. For an implant to the input quill: Perform applicable portions of the Lubrication Check Run, Para. 1.6.2.

b. Install the helicopter on the tiedown stand. Do not install the engine cowling or transmission cowling.

c. Verify that the helicopter has been lubricated and serviced. Visually inspect the following:

All tiedown points for security
Oil system for security and leakage
Fuel system for security and leakage
Hydraulic system for security and leakage
Flight controls for security
Engine accessories and controls for security, loose connections and proper operation

NOTE: Throughout the entire procedure, all components should be carefully checked for evidence of leaks and abnormal noise.

d. Start engine and bring to flight idle. Verify that all temperatures and pressures are within limits.

e. Perform the test outlined in the Maintenance Run Table G-III.

TABLE G-III

UH-1H
MAINTENANCE RUN
MAIN ROTOR DRIVE TRAIN IMPLANTS
TRANSMISSION

Step	Time - (hr)			Engine Input	
	Interval	Accum.	RPM	Torque PSI	Approx HP
1	0.2	0.2	Flight Idle - Flat Pitch		
2	0.2	0.4	6400	20	415
3	0.2	0.6	6400	30	686
4	0.2	0.8	6600	40	900
5	0.1	0.9	6600	⚠1 50	1144

⚠1 Hot day conditions may require more power than the engine is capable of producing. Do not exceed the power limits outlined in TM 55-1520-210-10.

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f. Stop the engine and perform the following inspections.

Remove the transmission jets and visually inspect for foreign materials, burrs and damaged jets. Clean and reinstall.

Remove Airmaze oil filter. Visually inspect for foreign material. Clean in solvent (Item 1, Table 13-15 of DMWR 55 1615-156) and reinstall.

Remove the magnetic chip detector and inspect for foreign materials or chips. Clean and reinstall.

G-1.5.3 Transmission Maintenance Run; Tail Rotor Drive Implants

The following procedure is recommended for maintenance check of transmission implants in the tail rotor drive system, i.e., off-set accessory and tail rotor drive quill, tail rotor sump quill, and tail rotor output quill.

a. For an implant to the TR output quill, perform applicable portions of the Lubrication Check Run, Section G-1.6.2.

b. Install the helicopter on the tiedown stand. Do not install the engine cowling or transmission cowling.

c. Verify that the helicopter has been lubricated and serviced. Visually inspect the following:

All tiedown points for security
Oil system for security and leakage
Fuel system for security and leakage
Hydraulic system for security and leakage
Flight controls for security
Engine accessories and controls for security, loose connections, and proper operation.

NOTE: Throughout the entire procedure, all components should be carefully checked for evidence of leaks and abnormal noise.

d. Start engine and bring to flight idle. Verify that all temperatures and pressures are within limits.

e. Perform the test outlined in Table G-IV, Maintenance Run.

f. Stop the engine and perform the following inspection:

Remove transmission jets and visually inspect for foreign materials, burrs and damaged jets. Clean and reinstall.

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TABLE G-IV

UH-1H
MAINTENANCE RUN
TAIL ROTOR DRIVE TRAIN IMPLANTS
TRANSMISSION/42 DEGREE GB/90 DEGREE GB

Step	Time - (hr)		Engine RPM	Coll. Pitch	Tail Rotor		
	Interval	Accum.			RPM	Pedal Input	Approx. HP
1	0.2	0.2	Flight Idle	Flat	-	Neutral	-
2	0.2	0.4	6400	↓	4170	△1 Full Right	46
3	0.2	0.6	6400	↓	4170	Full Left	87
4	0.2	0.8	6600	↓	4300	Full Right	50
5	0.2	1.0	6600	↓	4300	Full Left	90

△1 Full left pedal is defined as full deflection to the left pedal stop as set up in the Tiedown Instructions.

Remove Airmaze oil filter. Visually inspect for foreign material. Clean in solvent (Item 1, Table 13-15 of DMWR 55-1615-156) and reinstall.

Remove the magnetic chip detector and inspect for foreign material or chips. Clean and reinstall.

G-1.5.4 Maintenance Run of Transmission Accessory Quills

The following procedure is recommended for maintenance check of implants in the generator quill or the hydraulic pump quill.

a. Install the test quill in the transmission and check for backlash.

b. Prepare the helicopter for ground run. The tiedown facility is not required. Do not install the engine or transmission cowling.

c. Start the engine and bring to flight idle. Verify that all operating parameters are within limits.

d. Perform the following run cycle. Maintain neutral pedals and full down collective during run.

Step	Time Interval	Hours Accum.	Engine RPM
1	0.3	0.3	Flight Idle
2	0.3	0.6	6400
3	0.3	0.9	6600

e. Perform the following inspection on the universal transmission:

Remove the Airmaze filter. Visually inspect for foreign material. Clean in solvent (Item 1, Table 3-15 of DMWR 55-1615-156) and reinstall.

Check the magnetic chip detector for foreign material or chips. Clean and reinstall.

G-1.5.5 42-Degree and 90-Degree Gearbox Maintenance Run

The following procedure is recommended for maintenance check of implants in the 42-degree or 90-degree gearbox.

a. For an implant to the 42-degree gearbox, perform the Lubrication Check Run, Section G-1.6.3.

b. Install the helicopter on the tiedown stand. Do not install the gearbox fairings.

c. Verify that the gearboxes have been properly lubricated and secured.

NOTE: Throughout the entire procedure, all components should be carefully checked for evidence of leaks and abnormal noise.

d. Start engine and bring to flight idle. Verify that all temperatures and pressures are within limits.

e. Perform the test outlined in Table G-IV, Maintenance Run.

f. Stop the engine and perform the following inspection:

Check the magnetic chip detector for foreign material or chips. Clean and reinstall.

G-1.6 Lubrication Check Procedures

G-1.6.1 Introduction

Lubrication checks are specified in the following procedures:

Transmission green run (Section G-1.4.2)
42-degree gearbox green run (Section G-1.4.4)
Transmission maintenance run with input quill implant (Section G-1.5.2)
Transmission maintenance run with tail rotor output quill implant (Section G-1.5.3)
42-degree gearbox maintenance run (Section G-1.5.5)

The recommended procedures for conducting these checks on installed components are described herein. These procedures apply to the AIDAPS program only.

G-1.6.2 Transmission Lubrication Check Run

The following procedure is recommended for lubrication check of the main transmission as applicable in conjunction with transmission green runs and maintenance runs.

a. Install input driveshaft connecting transmission and input quill to engine. Do not install tail rotor driveshaft.

b. Slide oil seal back to clear nut, (#12, Figure 3-9 of DMWR 55-1615-156) P/N 209-040-185 on the tail rotor output quill assembly to allow oil to flow out.

c. On main input quill P/N 204-040-363-3, remove oil tube and install the external drain tube, Part No. 204-040-009-1 PAT-1D. On main input quill P/N 205-040-263-3, remove plug Part No. AN814-6DL and install oil evaluation fixture. Install tube to allow oil to drain into a 1000 ml container.

d. Remove lockwire from oil jets 2, 3, 4, and 7.

NOTE: Inspect all tiedown points for security.

e. Start engine and bring to 5800 rpm.

f. Check that oil pressure is within 50 to 55 psi.

NOTE: Replace oil as required.

g. Loosen No. 4 jet. Rotate to left and tighten. Measure flow from tail rotor output quill assembly. Oil flow shall be 100 ml/min or greater.

h. Loosen No. 4 jet. Rotate to the right and tighten. Measure flow from tail rotor output quill assembly. Oil flow shall be 100 ml/min or greater.

i. With No. 3 jet open, measure flow from main input quill assembly. Oil flow shall be 800 ml/min or greater and exceed oil flow from the next stop by 400 ml/min.

j. Remove No. 3 jet and install plugged jet Part No. 204-040-001-19 PAT-1D.

k. Measure flow from main input quill assembly. Oil flow shall be 400 ml/min or greater.

l. Remove plugged jet and install No. 3 oil jet.

m. Remove all test apparatus, lockwire jets, and inspect transmission for proper configuration.

G-1.6.3 <u>42-Degree Gearbox Lubrication Check-Run</u>

The following procedure is recommended for lubrication check of the 42-degree gearbox in conjunction with 42-degree gearbox green runs or maintenance runs.

NOTE: Inspect all tiedown points for security.

a. Install 42-degree gearbox without output shaft oil seal and do not install the tail rotor shaft to the 90-degree gearbox.

b. Start engine and bring to flight idle. A puddle of oil should accumulate at bottom outboard face of duplex bearing set within one minute. A broomstraw placed on the rotating inner race of bearing should deflect oil droplets in the air.

c. Stop engine and replace oil seal. Replenish gearbox oil.

G-1.7 Modifications To Prevent Input Driveshaft Failures

During initial tiedown operations at Fort Rucker, several input driveshaft failures were experienced. BHT assistance was requested in solving this problem. It was determined that the failures occurred while operating at high power with maximum forward cyclic input. The failures were apparently due to excessive misalignment between the engine and transmission under these conditions. Such misalignment would not occur during normal flight because the fuselage would be free to rotate.

Special transmission mounts for tiedown operation were successfully tested at BHT, and provided to the Army Aviation Test Board. The procedure for installing the mounts and related equipment was also provided, as follows:

a. Remove the four main pylon mounts per TM55-1520-210-34, Paragraph 7-6.

NOTE: Paint all nonstandard parts and filler plates yellow. DO NOT USE ON FLIGHT AIRCRAFT.

b. Replace the four 204-031-927-7 mounts (4500 in-lb standard) with the four J-8085-23 mounts (7500 in-lb test).

c. Remove one 100-055-1 filler plate from each forward mount position.

d. Remove one 100-055-3 filler plate from each rear mount position and install one in each forward mount position.

e. Rework two 100-055 filler plates to obtain a 0.040 ± 0.005 inch thickness. Install one reworked 0.040 inch filler plate in each aft mount position.

f. Complete the four main pylon mount installations and reshim the fifth mount per TM55-1520-210-34, Paragraph 7-6.

g. Remove the 209-030-357 lift link and replace with the 204-038-244 adjustable link.

h. Transmission is now ready for installation per TM55-1520-210-34, Paragraph 7-2.

It is not considered necessary to change the standard transmission mounts during the UH-1H maintenance runs with transmission implants. To prevent any main driveshaft failures during the maintenance runs, the following modifications are suggested for the procedures of Section G-1.5.2.

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- Eliminate Step 5 in Table G-III.
- Reduce the "Interval of Step 4 to 0.1 hour. (The "Accum. Time" of Step 4 becomes 0.7 hour).

Experience with tiedown operations at BHT indicates that the 205-040-004-3 main driveshaft should be installed in preference to earlier model driveshafts. Continuous small cyclic stick motions are beneficial to assist in proper lubrication of the internal parts of the driveshaft and should be included in the tiedown test procedures.

G-1.8 Special Schedule and Limits for High Ambient Maintenance Runs of Tail Rotor Drive Implants

It was found during high ambient tiedown runs at Fort Rucker that the 42-degree and 90-degree gearbox oil temperature limit of 212° was reached during Step 5 of the maintenance run schedule of Table G-IV. A modified procedure was developed by USAADTA whereby the run consisted of going through the steps of Table G-IV twice, but holding each point for half the specified time. This permitted the gearboxes to cool at the low power points, after reaching maximum temperature at the end of Step 5. Even so, additional cooling time was required, and BHT assistance was requested.

Tests in the BHT Transmission Research Laboratory indicated that the temperature limit could be safely increased to 230°F for short periods. Therefore, for purposes of this test only, BHT recommended that the gearbox oil be allowed to reach 230°F. This limit, in conjunction with the revised test schedule, enabled the runs to be completed in the specified 1-hour interval.

G-2.0 AH-1G TIEDOWN EQUIPMENT AND PROCEDURES

G-2.1 Introduction

It was originally planned that implants would be tested in AH-1G helicopters. Therefore, tiedown equipment, modifications, and procedures were developed by BHT as reported herein. The AH-1G was subsequently deleted from the AIDAPS program; therefore no tiedown runs were made.

G-2.2 General Operational Procedures

a. The tiedown pad should be flat and level, and should completely contact the skid gear.

b. Rubber pads under the skid gear should not exceed 1-inch in thickness.

c. Prior to each run, remove both tailboom lower doors, inspect door frames for cracks and nutplates for looseness, and replace doors and attachments.

d. Remove engine cowling and 42-degree gearbox cowling to provide increased airflow to the input driveshaft and 42-degree gearbox.

e. The tailboom tiedown cables should be approximately 25 feet long, and oriented perpendicular to the aircraft centerline. Cables should be "snug" (not slack).

f. The tiedown fitting and skidgear restraints should be installed with all slack removed, but not heavily preloaded.

g. Aircraft gross weight should be the minimum practical.

h. Pedal inputs should be made slowly and smoothly to avoid dynamic loading effects.

i. Cyclic stick movements at high speed and power points should be limited to the small movements required for input driveshaft lubrication.

G-2.3 Specific Test Procedures

AH-1G procedures for tiedown green runs, maintenance runs, and lubrication checks are identical to the corresponding UH-1H procedures.

G-2.4 Tiedown Modifications and Equipment

G-2.4.1 Commonality With UH-1H

Use of the following items is the same as for the UH-1H:

Tiedown tool (Section G-1.3.1)
Skid gear restraint (Section G-1.3.5)
Special transmission mounts (Section G-1.7)

G-2.4.2 Cyclic Stick Limiter Fabrication and Installation

Figure G-3 shows the AH-1G cyclic stick limiter design. To install the limiter, the gunner's cyclic stick boot (P/N 209-001-335) is removed, and replaced by the limiter. Tape should be wrapped around the stick where it contacts the limiter to prevent abrasion.

G-2.4.3 Left Pedal Stop

The left pedal stop consists of an MS21919DG clamp, as shown by Figure G-4. The clamp is installed as follows:

a. Attach a portable hydraulic test unit and apply hydraulic power per Chapter 6, TM55-1520-221-20.

NOTE: Make from .064 aluminum sheet

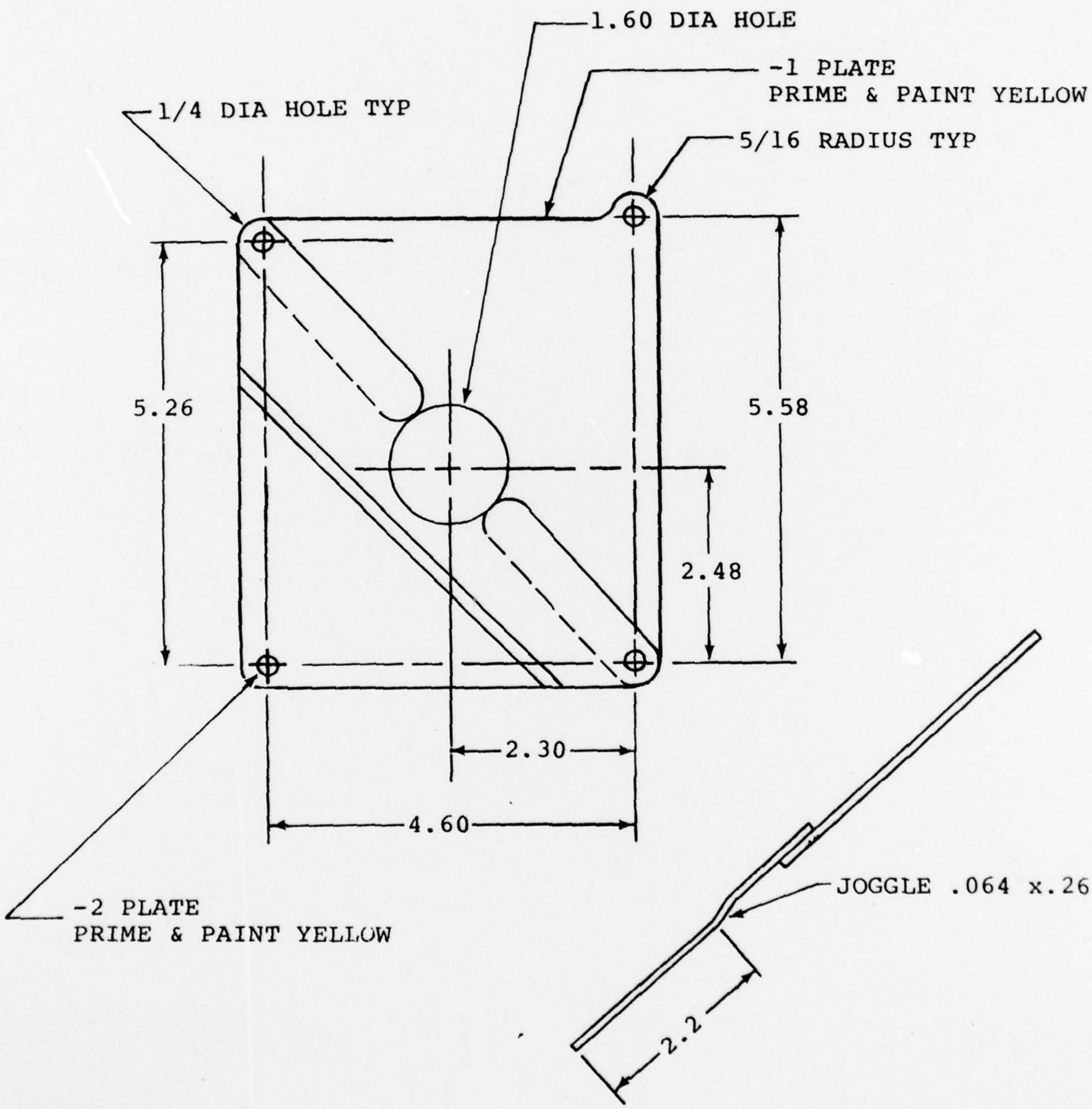
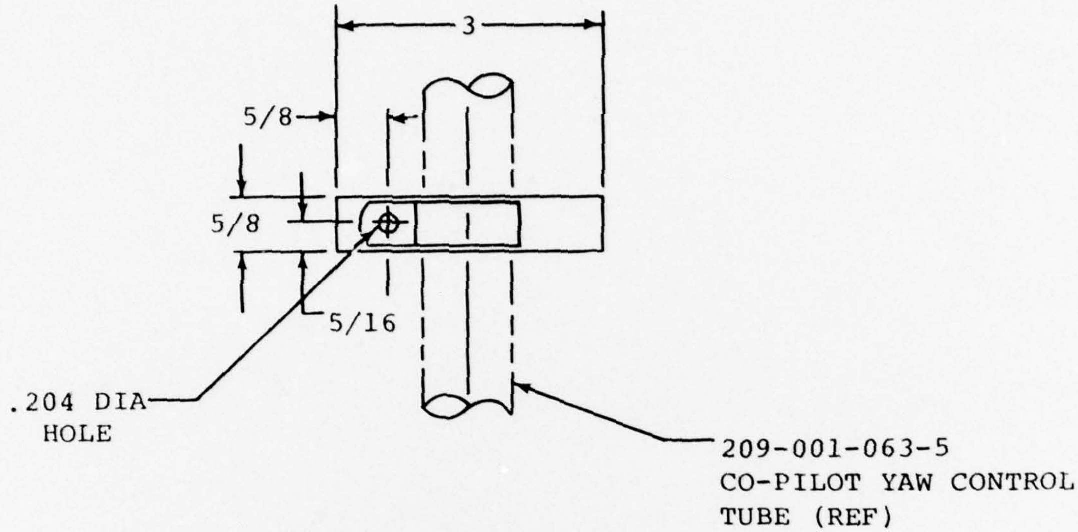


Figure G-3. AH-1G cyclic stick limiter for tiedown operation.



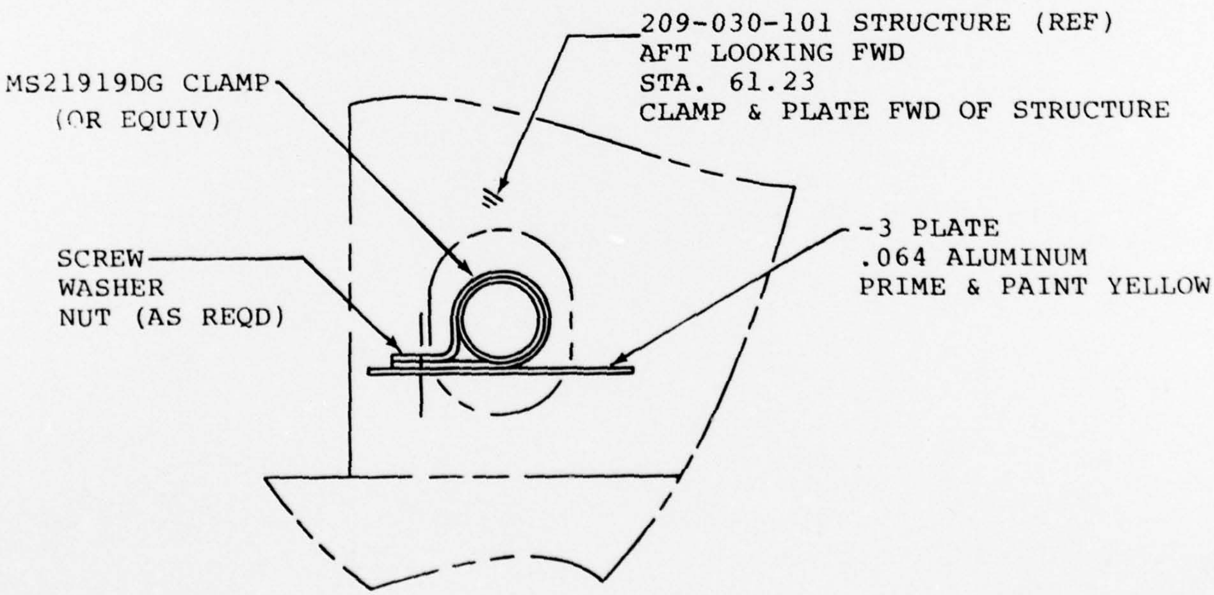


Figure G-4. AH-1G AIDAPS tiedown left pedal stop.

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b. Cycle pedals full right and left and half full left pedal.

c. Turn tail rotor to horizontal position.

d. Set a propeller blade protractor to zero index. Place protractor on flat surface of tail rotor just outboard of grip.

NOTE: During this series of measurements, maintain the orientation of protractor the same throughout. That is, the spirit level must be on the forward side for all readings, or on the aft side for all readings.

e. Flap rotor in one direction against static stop. Measure and record protractor reading. Flap blade in opposite direction to stop and record reading.

f. Place protractor with same orientation on the opposite blade. Repeat step e.

g. Add four recorded protractor readings. Divide by four. Average blade pitch angle should be 19 degrees ±1/4 degree.

h. Apply right pedal and install the tiedown pedal stop on the gunner's yaw control tube per Figure G-4.

i. Apply left pedal until the blade protractor reads 11-1/2 degrees. Hold 11-1/2 degrees and move the pedal stop until stop contacts the bulkhead.

j. Repeat steps e and f.

k. Determine average pitch angle as in Step g. The average blade pitch angle should be 11 1/2 degrees ± 1/4 degree.

l. If the blade readings are not satisfactory, adjust the tiedown pedal stop and repeat steps j and k until the protractor readings are within limits.

G-2.4.4 AH-1G Tail Boom Tiedown Modifications and Equipment

The tailboom should be modified for tiedown operation per Figure G-5. The tiedown fitting is the same as the UH-1H fitting (P/N 212-HES-295), except for the following changes in width dimensions:

From	To
1.90	2.16
1.40	1.66
2.12	2.28
5.46	6.02

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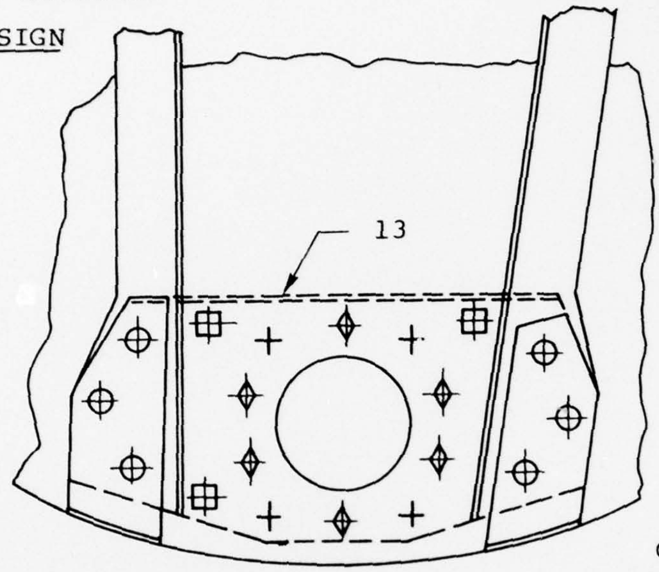
B. STA. 227.0 BULKHEAD

PRESENT DESIGN

REF. DWG. NO. 209-030-838



VIEW LOOKING FWD

○ DD RIVETS #6

□ AD RIVETS (PROTRUDING HEAD)

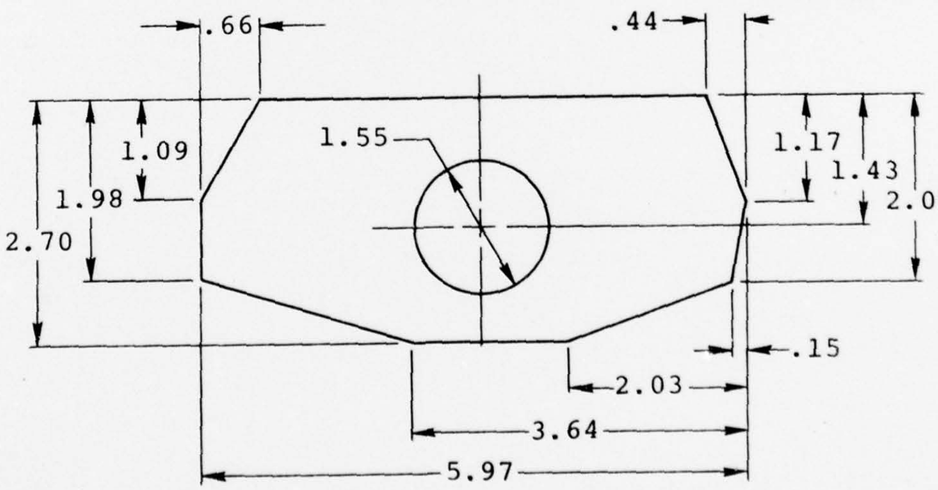
◊ AD RIVETS (CSK)

+ NUT PLATES FOR STINGER ATTACHMENT

MODIFICATION REQUIRED

REMOVE -13 DOUBLER

REPLACE WITH 1/8" ALUM. P/L-2024-T3



REPLACE 1/8 AD RIVETS WITH 5/32" AD RIVETS

Figure G-5. AH-1G tailboom modification for tiedown operation.

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G-3.0 UPRATED TRANSFORMER INSTALLATION

Power requirements of the prototype AIDAPS airborne equipment exceeded the capability of the standard UH-1H 28-Vac/50 VA transformer, P/N 9T39Y5. Per AVSCOM request, BHT investigated the problem, and recommended substitution of a P/N 209-075-363 transformer, rated at 28-Vac/150 VA.

The procedure for installing the uprated transformer is as follows:

a. Remove existing 9T39Y5 transformer from nose compartment.

b. Remove the nutplates used for mounting the 9T39Y5 transformer.

c. Drill mounting holes in nose compartment shelf per Figure G-6.

d. Install the 209-075-363 transformer on the shelf (electrical terminals facing forward) with 4 each MS35207-261 bolts, AN 960 C10L washers, and MS 21042-L3 nuts.

e. Install electrical leads. The terminal studs on the 209-075-363 transformer are identical with those of the 9T39Y5 transformer.

G-4.0 CARGO FITTING FAILURE INVESTIGATION

The attachment point for the UH-1H tiedown tool is the cargo sling fitting, P/N 205-030-107-1. In August of 1975, one of these fittings failed at Fort Rucker, and was returned to BHT for investigation. The BHT findings are as follows:

- Both vertical members of the fitting were broken and completely separated, as illustrated in Figure G-7.
- The forward vertical member failed first and was broken through both bottom bolt holes.
- The aft vertical member failed last and was broken through the bolt holes and the bottom row of rivets; it was bent backwards and apparently failed in a combination of tension and bending.
- There is evidence of fatigue originating at the outside surface of both vertical members' bolt holes (opposite the nutplates) as indicated in Figure G-7. The fatigue covered about 30 percent of a cross-section through the bolt holes.
- The holes were oversize, rough, not deburred and showed evidence of thread bearing.

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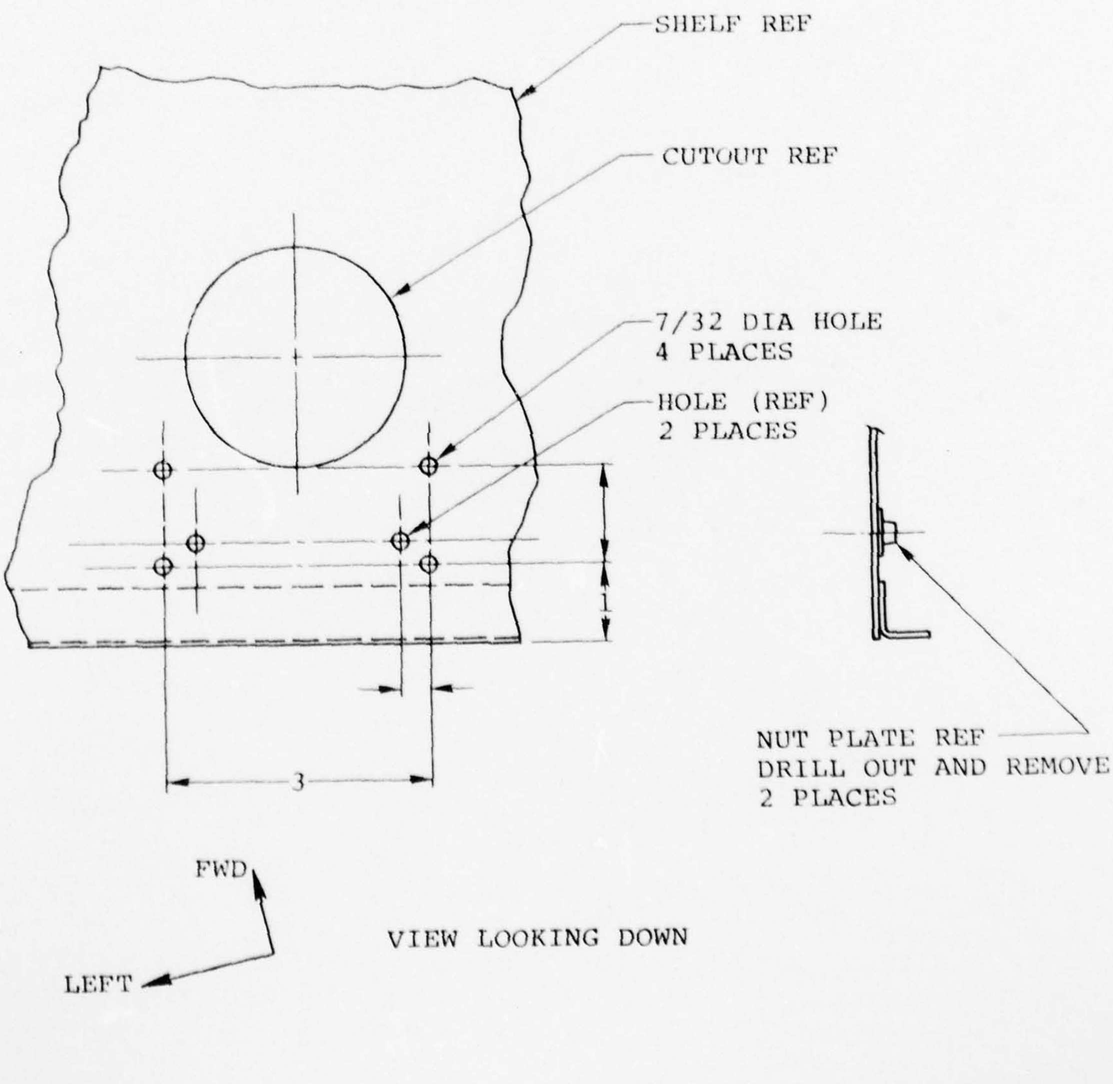

Figure G-6. Nose compartment shelf modification sketch.

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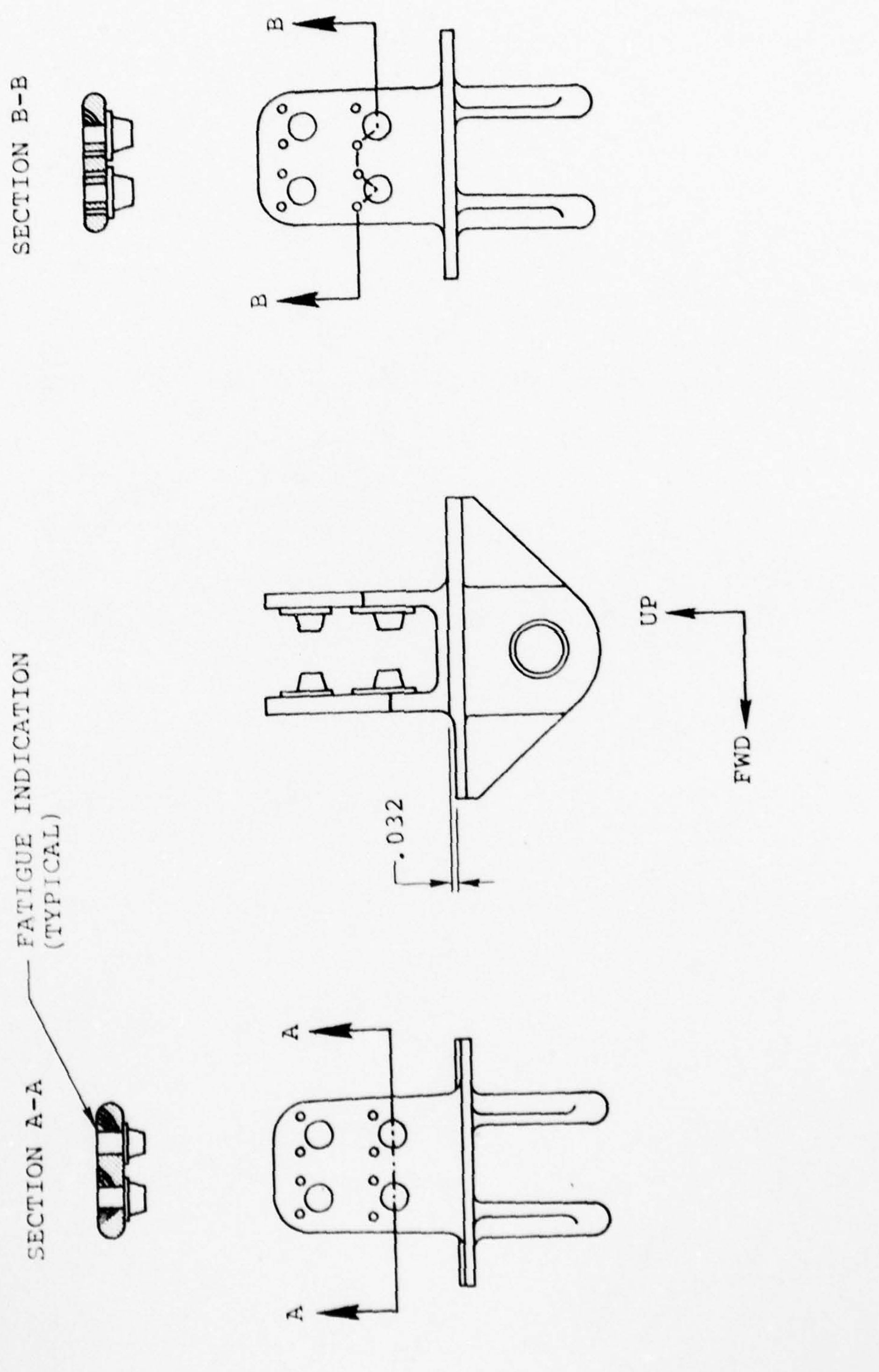

Figure G-7. Cargo sling fitting, P/N 205-030-107-1

- A hardness test confirmed the forging was 7075-T6 aluminum as required.

- The possibility exists that one vertical member may have been highly loaded due to an offset of the tiedown tool.

The broken fitting reportedly was used for 83 hours of tiedown operation while installed in Bearcat #13. BHT requested, via Telecon with Hawthorne Aviation, that the fittings from the remaining three AIDAPS test aircraft be removed and inspected for cracks at the suspected initiation area by the dye penetrant method. These inspections revealed no evidence of cracks. Tiedown operational times of 10, 30, and 110 hours had been recorded on these fittings.

The BHT Field Investigation Laboratory records show one similar failure (in 1968). The analysis has been cleared from the files. Field Service records indicate no failed fittings in operational service. Field Service personnel remember that the USAF had broken a cargo fitting while operating on tiedown when a tiedown tool was not properly installed.

The horizontal plate that bolts to the bottom of the lift beam is not in one plane. The forward surface is lower by 0.032 inches than the aft surface, as indicated in Figure G-7. The maintenance manual is incomplete in that it does not specify a fore and aft position requirement.

The following cautions were recommended for tiedown operation of the four AIDAPS helicopters at Fort Rucker, Alabama, for the remainder of the program:

- Position the helicopter so that the cargo hook fitting is directly over the ground tiedown fitting.

- Load the helicopter to maximum gross weight.

- Install the skid cross ties.

- Preload the tiedown tool to 525 in-lb of torque.

- Remove the cargo hook fitting after each 10 hours of tiedown operation and inspect the outer surface (opposite the nut plates) for cracks at the bolt and rivet holes using the zyglo or dye penetrant method. If cracks are visible replace the fitting.

- Upon reinstallation of the fitting, be sure that the fitting is positioned correctly in the fore and aft direction.

- Upon removal of the helicopters from the AIDAPS program, remove the cargo hook fittings, strip the paint and inspect

for cracks by the zyglo method. If cracks are visible, replace the fitting.

It appears that the failure of the fitting was induced by rough hole edges and oscillating loads while operating on the tiedown pad. Preloading the tiedown tool prevents oscillatory loading through the cargo hook fitting.